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SUPREME COURT, U. S.

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E. ROBERT SEAVER

IN THE

Supreme Court of the United States

October Term, 1971

Docket No. 71-363

BECKMAN INSTRUMENTS INCORPORATED,

Petitioner,

v.

REEVES INSTRUMENT CORPORATION and DYNAMICS CORPORATION OF AMERICA,

Respondents.

APPENDIX TO RESPONDENTS' BRIEF IN OPPOSITION TO PETITION FOR WRITS OF CERTIORARI AND/OR MANDAMUS

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Order for Preparation of Findings of Fact, Conclusions of Law and Interlocutory Judgment

UNITED STATES DISTRICT COURT

CENTRAL DISTRICT OF CALIFORNIA

Civil No. 64-135-HP

REEVES INSTRUMENT CORPORATION and DYNAMICS CORPORATION OF AMERICA,

Plaintiffs,

v.

BECKMAN INSTRUMENTS INCORPORATED,

Defendant.

This case was tried by the Court without a jury and was submitted for decision on May 24, 1968.

After consideration of all the evidence, the briefs, and the arguments of counsel, the Court decides in favor of plaintiffs and against defendant as follows:

1. U. S. Patent No. 2,967,997, issued January 10, 1961, covering "Method and Apparatus for Checking Analog Computers" is valid with respect to the claims in suit, namely, claims 7, 8 and 13.

2. Defendant Beckman's 2100 and 2200 series General Purpose Electronic Analog Computers infringe said claims 7, 8 and 13 of said U. S. Patent No. 2,967,997.

3. Plaintiffs are not entitled to an award of attorneys fees from defendant.

4. Plaintiffs are entitled to an award of damages adequate to compensate for the said infringement. Said damages to be limited to the amount assessed. The Court will not increase damages over the amount assessed.

5. Plaintiffs are entitled to recover from the defendant their costs.

6. The issue of damages to be referred for hearing to a master pursuant to Rule 53 of the Federal Rules of Civil Procedure.

7. Plaintiffs to prepare proposed findings of fact, conclusions of law and interlocutory judgment within 21 days as per Local Rule 7.

IT IS ORDERED that the Clerk of the Court shall this day serve copies of this Order, by United States mail, upon the attorneys of record for the parties appearing in this cause.

Dated: June 7, 1968.

HARRY PREGERSON

HARRY PREGERSON
United States District Judge

Findings of Fact and Conclusions of Law

IN THE

UNITED STATES DISTRICT COURT

FOR THE CENTRAL DISTRICT OF CALIFORNIA

[SAME TITLE]

Findings of Fact

A.

General Findings

A1. Plaintiff Dynamics Corporation of America (DCA) is a corporation of the State of New York having its principal place of business at 501 Fifth Avenue, New York, New York.

A2. Plaintiff Reeves Instrument Corp. (Reeves) having a place of business in Garden City, New York, was a corporation of the State of New York but is now merged into and is a division of plaintiff Dynamics Corporation of America.

A3. Defendant Beckman Instruments Inc. (Beckman) is a corporation of the State of California having its principal place of business at 2500 Harbor Boulevard, Fullerton, California.

A4. In this action, commenced January 30, 1964, plaintiffs charge defendant with infringement of U.S. Patent 2,967,997 (the patent in suit) entitled "Method and Appa-

ratus for Checking Electronic Analog Computers." The patent was issued on January 10, 1961, on an application of Rawley D. McCoy, filed on April 20, 1955.

A5. Plaintiff DCA has been assigned all right, title and interest in and to U. S. Letters Patent 2,967,997 and causes of action accruing thereunder.

A6. The patent in suit discloses a "Problem Check" system for statically and dynamically checking general purpose electronic analog computers. Only the static checking system of the patent is involved in this action. It is the subject matter of claims 7, 8 and 13 of the patent in suit which defendant Beckman is accused of infringing through the manufacture, use and sale of its 2100 and 2200 series general purpose analog computers.

A7. Related actions charging infringement of the patent in suit have been brought by plaintiffs against Electronic Associates, Inc. (pending in the U.S. District Court, District of New Jersey) and against the United States Government (pending in the U.S. Court of Claims).

B.

History of Analog Computers and Their General Operating Characteristics

B1. General purpose electronic analog computers to which the patent in suit relates were first developed and commercialized following World War II using components developed during the War for computing the answers to

artillery problems. Reeves commenced the operation of a large analog computing facility known as "Project Cyclone" in 1946 and began selling such computers in 1948. In 1945, the Massachusetts Institute of Technology began development of a large facility known as the "DACL" which became operational in 1948. Starting in 1948, other facilities were developed, principally at aircraft and aerospace companies and at various government and research laboratories throughout the country.

B2. Defendant Beckman commenced the manufacture and sale of general purpose analog computers in 1952. Other companies in the field from relatively early dates included Radio Corporation of America (RCA), Goodyear Aircraft, Boeing Aircraft, Mid Century and Electronic Associates, Inc.

B3. The rapid growth of computers following World War II played an important role in the design of complex aircraft, autopilots, weapon systems and space vehicles. Computers have become indispensable tools in the design of these systems and devices because the behavior thereof cannot be precalculated or defined by straightforward mathematics.

B4. The general purpose analog computer consists of groups of electronic computing elements housed in cabinets and designed to perform various mathematical operations such as addition, subtraction, division, multiplication, trigonometric resolution, function generation and integration. The principal computing elements are called po-

tentiometers (a form of multiplier), summers, multipliers, resolvers, function generators and integrators (Tr. 32-33, 57-119).

B5. The particular type of analog computer involved in this suit is known as the general purpose type because it can be used to solve a wide variety of problems accomplished by interconnecting the computing elements in various patterns as dictated by the particular problem to be solved. Unlike special purpose pre-wired computers, the general purpose type is in the nature of a "warehouse" or "complex of electronic building blocks" capable of forming an almost infinite number of different combinations (Tr. 788).

B6. In order to permit any desired interconnection of the computing elements, the computer is provided with a "patch bay" which makes accessible to the operator all of the input and output terminals of the computing elements. The computer is also equipped with Jumper wires known as "patchcords" for interconnecting the computer components. The patchcords are first inserted in a perforated panel (called the "patch panel" or "patchboard" or "problem board") in accordance with the required pattern of interconnection; the patch panel is thereafter inserted in the patch bay to thereby interconnect the computer components in the configuration or pattern required to solve the problem. The operation of inserting the patchcords is known as "patching" (Tr. 30-40, 54-57). The Court observed such patching operations on a number of occasions during the trial (Tr. 150-153).

Findings of Fact

B7. In a typical problem there are at least several hundred, and often several thousand, patchcords which must be inserted into the patchboard. As was demonstrated by several of the exhibits which were received in evidence, the result is a mass of many hundreds of closely packed and tangled wires (Tr. 51-55, Px 353).

B8. In addition to the interconnection of computing elements accomplished by the patching operation, the "programming" of the analog computer also requires the adjustment and positioning of various dials and switches as required by the particular problem being solved. Often hundreds of such adjustments must be made in typical problems (Tr. 40-41, 165-166).

B9. The integrator is unique as compared to other computing elements in that it is the only dynamic element, i.e., the only element in which the output value changes even though the input signal applied thereto may remain fixed. Since the analog computer is normally used to solve dynamic problems (integral calculus problems and differential equations), the integrators are the centers of activity. Control over the different operating modes in the computer is achieved through the integrators (Tr. 102, 166-174).

B10. The integrators also form the focal points of the signal flow paths through the computing elements. When an analog computer is solving a problem, the electrical signals flow in a rather complex maze of closed-loop circuit paths with each such closed-loop path passing through at

least one integrator. As a consequence, signals emerging from an integrator will flow through other computing elements and then eventually return to the integrator (Tr. 117-118) (Also Tr. 225).

B11. At all times pertinent to this case, the basic component of most computing elements is an electronic device known as an operational amplifier. The operational amplifier is a high gain DC amplifier capable of receiving a signal at its input and providing an enlarged version (typically magnified by a factor of ten million) thereof at its output. By combining the operational amplifier with other electronic devices, the various computing elements or building blocks such as integrators, summers, multipliers, etc. can be formed (Tr. 79-82, 93-94, 97-98, 108-112).

An electronic integrator of the type described in the patent in suit includes an input resistor network, an operational amplifier connected in series with the input resistor network, and a feedback condenser connected around the amplifier. Connection to the integrator from the patchcords supplying signals thereto are made via spring contacts in the patchbay and associated connections to the resistor network. The inputs to the integrator include the input resistor network and the associated connections thereto. (Px 5, 500192 et seq.; Px 296, Col. 2, lines 18, 24, 37; Col. 3, lines 20-58; Tr. 85-88, 94-97, 102-103, 291, 308, 453, 454, 553 and 833-835).

B12. The potentiometer (also called a "pot") is an example of a simple type of computing element which does

not include an operational amplifier. It is a variable electrical resistor provided with a dial and adjusted by the operator to vary the level of signals within the computer, i.e., to multiply signal levels by a selected coefficient (Tr. 59-76).

B13. In solving the equations characterizing the problem, the computer may be said to be electronically simulating the behavior of the various quantities represented in the problem equations. Since these quantities are in turn mathematical representations of physical quantities, the computer is frequently referred to as a "simulator" of these physical quantities. The art of using the computer is likewise referred to as the art of simulation. By solving the equations which define the behavior of a missile, for example, the computer is actually simulating the flight of the missile and produces representations of its trajectory, attitude, altitude and the like (Tr. 133-136).

B14. After the computer has been set up or programmed to solve a particular problem, i.e., to simulate a physical system, certain checks are performed and computations thereafter initiated (Tr. 153-154). Checking has been a common practice throughout the development of analog computers.

B15. The answer supplied by the analog computer is generally presented as a curve or series of curves traced out by a recorder. These curves depict the behavior of the problem being solved. The equations in turn simulate the dynamics of a real system (Tr. 41-50). During trial,

plaintiffs demonstrated a computer simulation of a cannonball trajectory utilizing a large Milgo computer. Defendant demonstrated a computer simulation of a pendulum movement using a small EAI desk top model designated TR 20 computer (Tr. 911 et seq.). The operation of these computers in tracing out the answers was observed by the Court and several recordings representing computer answers were explained and received in evidence.

C.

The Problem of Checking the Computer and Its Importance

C1. Unlike the case with other machines the performances of which are known and verifiable, an inspection of the answers produced by the analog computer generally fails to reveal whether the computer is operable and has been properly patched and adjusted (Tr. 155). Whereas the inspection of the output of a conventional device such as a television set reveals whether or not it is in operating condition, the inspection of the curves produced by the computer are not so instructive because the correct curve is not known to begin with, and in many cases the computer answer will seem "completely reasonable" (Tr. 1462) and will still trace out "wiggly lines even if there is something wrong" (Tr. 791) such as a malfunctioning component, a misplaced patchcord or an improperly set dial (Tr. 789-791). In this respect the problem of verifying the solution of a general purpose computer is unique. The literature of the art put in evidence by both parties and referred to hereinafter attests to the seriousness of this problem and its widespread concern to those skilled in

the art. There is also the possibility that the equations do not correctly describe the physical problem, thereby adding more complications to the overall problem of computer use.

C2. A second factor complicating the problem of checking the computer is its vulnerability to human error. The need to manually perform thousands of patchcord connections and to adjust hundreds of computing elements creates an exceedingly high probability that a human error will occur (Tr. 55-56, 187). In observing patching and adjustment operations the likelihood of such errors was manifest to the Court, a conclusion confirmed by the testimony of many witnesses of both plaintiffs and defendant.

C3. The physical condition of the fully wired patchboard with its mass of tangled patchcords provides a further aggravating factor in the checking problem. The correct location of the patchcords and proper seating in their respective holes is difficult to check visually; the access to the holes and cord terminals for checking purposes is physically impeded; and the manipulation of the cords inevitably disturbs the adjacent cords creating the danger of unseating patchcord terminals or causing a break in the patchcord conductor (Tr. 55-57, 187).

C4. After observing fully wired patchboards and manipulations on them, the Court finds that the literature has aptly described the patchboard as a "bewildering maze" and a "jungle of confusion." J. L. Burnside of

North American Aviation stated in the Project Cyclone Symposium I of March 1951 that:

> "Patchcords, we feel, fail in three main ways. First, they are physically frail and unreliable; second, they are awkward to handle in setting up a problem and offer many possibilities for error; and third, they present in the complete problem a formidable jungle of confusion that makes checking and verification both tedious and exasperating." (Px 230, page 47)

C5. A further complication in the problem of checking the computer lies in the danger of disturbing the computer setup in the course of checking it. This would "destroy the very thing that you are attempting to check" (Tr. 472). Any checking procedure which requires the temporary removal of patchcords or the readjustment of dials, suffers from a serious defect in that the operator may inadvertently neglect to replace the patchcord or readjust the component after the conclusion of the checking operation. Should this occur, an invalid solution results. As stated in the 1965 "Handbook of Analog Computation" (Px 85) published by Electronic Associates, Inc. (defendant in the previously noted New Jersey action):

> "Any check which necessitates important patching changes to restore the problem conditions after the check conditions, introduces the very serious danger of an error in these patching changes, an error that cannot be detected." (page 272)

C6. Finally, a check of the analog computer must necessarily be complete since it only takes one error or mis-

adjustment or malfunctioning component to completely destroy the validity of the computer solution.

C7. Statements in the above noted 1965 "Handbook of Analog Computation" (Px 85) are also apt on this point.

> "*Need for Static Check*—* * * On moderately large problems (over 100 amplifiers) it is very rare that the entire program will be completed without error. Even on fairly small problems (50 amplifiers or less), an experienced programmer still may make a mistake or two. Component malfunctions occasionally occur, even with well maintained equipment, and, again, one faulty resistor can invalidate the entire result.
>
> * * * Those errors and malfunctions are typical of the difficulties encountered in programming and running an analog problem. A systematic check must locate *all* such errors, since a single error (or component malfunction) can make the entire simulation invalid." (page 127—emphasis in original)

C8. An invalid solution can lead to serious consequences because the computers are relied upon as design tools in the development of complex and costly systems. The validity of the computer solutions is therefore critical. L. M. Warshawsky who heads the Air Force analog computer facility at Wright Air Development Center (WADC) testified that the answers obtained at his computing facility were

> "used in making decisions in the design of air weapons systems that run into the millions, tens of millions and maybe billions of dollars and because of the

size of this facility our place was often the point of last determination as to which course to pursue. So when you are involved in decisions involving these huge sums, any means justifies the end, any labor that we put forth is justified to insure that the solutions we get are valid." (Tr. 705)

C9. There is ample and persuasive evidence in this case of widespread recognition of the importance of checking the computer and the extensive efforts by workers in the art to mitigate the checking problem. Examples of such efforts and their failure to achieve a solution are discussed hereinafter in findings dealing with the defenses. In general, all of the prior art checking arrangements and techniques advanced by the defendant against the patented invention involved either a disturbance of the computer setup, thereby aggravating the human error problem, and/or a failure to provide a complete check. This was the state of the art at the time the invention was made.

D.

The Patent in Suit

D1. The patent in suit teaches a static checking arrangement known as "Problem Check" which was designed to overcome the defects and shortcomings of prior static checking arrangements (Tr. 204, 205). With the Problem Check arrangement, a complete static check of all the computing elements is achieved through the measurement of a signal at each integrator which is known as the "initial value of the derivative." Not only is this static

check complete, but it is achieved without disturbing the computer setup, thereby obviating the danger of introducing human errors during the course of performing the check (Tr. 216-222, 224, 228, 353, 465-472, 475, 480-482, 486-487, 2060; Px 296, Col. 4/68-70, Col. 5/1-20).

D2. The patent in suit stresses the significance of making a complete check including a check of the "problem coding, patch connections and scale factor potentiometer settings" and further stresses the importance of checking the computer *after* a particular problem is set up to thereby avoid human errors resulting from the disturbance of the computer setup (Tr. 464-469).

> "Electronic computers are recognized today as being indispensable tools in the field of Dynamic Systems Engineering. Generally speaking, present day electronic computers have excellent accuracy, but this accuracy is meaningful only if the computer setup which includes problem coding, patch connections and scale factor potentiometer settings are free from error and the components of the computer are operating properly. In setting up a computer for the solution of a particular problem, several hundred or more connections and settings may have to be made by the operator and there is always the possibility of human error in addition to the possibility of improper operation of the components in the computer. Hence, it is of the utmost importance to be able to check the operation of the computer after it has been set up for the solution of a particular problem in order to establish the validity of the results obtained." (Column 1, lines 36-53 of the patent in suit.)

Findings of Fact

D3. The patent states that one of the specific objects of the invention is to achieve a complete check *without disturbing* the computer setup (Tr. 469-472).

> "An object of the invention is to provide a method and apparatus by means of which the connections, settings and functioning of the various components of an electronic computer may be readily checked and verified. In accordance with the present invention, such a check may be repeated as often as desired without disturbing the connections or setup of the computer." (Column 1, lines 18-24)

D4. The essence of the Problem Check static as taught by the illustrative embodiment of the patent in suit is the measurement of the initial values of the derivatives applied to the integrators with a known set of test voltages while avoiding any need for disturbing the computer setup (Tr. 475-482, 487-490).

D5. The patent claims involved in this suit, namely, claims 7, 8 and 13, define the electrical means or electronic structure for accomplishing the measurement described in D4 and are in accord with the objectives of the invention previously described in D2 and D3. (Tr. 216-222, 357, 475-482, 486-488, 497, 498, 502, 510-520, 526-531, 600, 2060).

D6. As taught in the patent, switching devices (relays) within the integrator circuits are used to establish the necessary circuit conditions for a special checking mode, thereby eliminating the need for manual disturbance of the computer setup. In the checking mode, the integrator is

rendered ineffective so that it does not function as an integrator, this being achieved by connecting a shunt resistor across the amplifier of the integrator. At the same time, a set of known test voltages are established in place of the normal integrator output signals (Tr. 211, 216, 241, 476-479).

D7. When the computer is placed in this special checking mode after having been set up for the solution of a particular problem, the known test voltages flow through all the computing elements and patching connections between computing elements to ultimately establish initial derivative signals which appear at the summing junctions of the integrators (Tr. 241, 242, 357, 479-480, 497-503).

D8. Persons skilled in the analog computer art have always recognized the extreme sensitivity of the integrator summing junction and have generally sought to stay away from this point so far as measurement is concerned (Tr. 89, 319, 359, 1687, 1689). As one witness put it, the summing junction is all right "as long as you don't touch it" (Tr. 1693). The voltage at the summing junction is an extremely minute quantity, being less than a millionth of a volt under typical conditions. As a result, the summing junction is often referred to as a "virtual ground" or essentially zero voltage point. The voltage at the summing junction is too small to be measured with any normal voltage measurement instruments (Tr. 89-90, 263-264, 499-501).

Findings of Fact

D9. The teachings of the patent upset this tradition and established that measurement of the initial value of derivatives, done in such a way as to avoid disturbance of the computer setup, will provide a complete static check of the computer setup (Tr. 217-218, 222).

D10. The patent teaches that the initial value of the derivative can be measured by means of a negative feedback amplifier (an amplifier with a shunt resistance connected across the amplifier) coupled to the integrator summing junction. The signal voltages applied to the input resistor network of the integrator are combined to form the initial derivative signal which flows through the summing junction as a current and produces at the output of the amplifier a measurable voltage which is proportional to the initial value of the derivative (Tr. 216, 217, 241, 480-487, 497-503).

D11. This Problem Check arrangement of measuring the initial derivative using a known set of test voltages after the computer is set up, is summarized in the patent specification as follows:

> "After the computer has been connected with the proper settings for the computation of a particular problem, a static problem check is first carried out. Under such conditions, the relay P.C. is energized and a constant problem check voltage from the potentiometer 53 is substituted in the computer for the output of the integrator. The relay X is also energized and thus, the amplifier does not function as an integrator. This is done for each integrator in the computer and

with the introduction of these constant voltages, output voltages will appear at each component in the computer, the values of which may be read and recorded by the readout device. Under these conditions, the outputs of the integrators will be proportional to the initial value of the derivatives applied thereto" (Column 4, lines 56-70).

D12. As disclosed in the patent, the test voltages are automatically removed when the computer is placed in any operating mode other than the special static checking mode so that the test voltages will not interfere with normal operation in the compute mode (Tr. 488-489).

D13. As stated in the patent, with the Problem Check arrangement there is no need to manually disturb computer connections (Tr. 489-490).

> "By incorporating the three control relays and the associated circuits in the integrators for a computer, the necessity for manually modifying any computer connections whatsoever in the performance of both the static and the dynamic problem checks is avoided and enables the operator to check the operation of the computer whenever desired by merely operating the appropriate switches" (Column 6, lines 28-35).

D14. Not only do the derivative measurements according to the teachings of the patent provide a complete static check of the computer without requiring a disturbance of the computer setup, but the derivative measurements also relate the computer setup back to the original equations. This relationship is noted in the patent as follows (Tr. 481-485):

"It will be noted that the outputs of integrators 10 and 16 are proportional to the initial value of the derivative or the normal integrator output. The values of the derivatives V and O are determined from the Equations 1 and 2, respectively" (Column 5, lines 15-19).

D15. The amendments to the specification made during the pendency of the application of the patent in suit were of a minor and editorial nature only (Dx CF, pages 26, 27; Tr. 1854-1855). The patent specification, which is substantially the same as originally filed in the Patent Office, is in accord with, and fully supports, each of patent claims 7, 8 and 13. These claims particularly point out and distinctly claim subject matter which is the same as that indicated, suggested and described by the originally filed application therefor.

D16. The patent specification contains a written description in such full, clear, concise and exact terms as to enable any person skilled in the art of analog computers to make and use the same, and sets forth the best mode contemplated by the inventor for carrying out his invention.

E.

Development of Problem Check and Its Impact on the Industry

E1. The historical incidents leading to the making of the invention and its successful implementation and adoption were presented by plaintiffs' witness L.M. Warshawsky and by documentary evidence and deposition testimony corroborating and complementing his testimony.

Findings of Fact

E2. Warshawsky is employed by the U.S. Government as Chief of the Analog and Hybrid Computation Facility at the Wright Patterson Air Force Base in Dayton, Ohio, which facility is sometimes referred to as WADC (Tr 610, 611). His intimate association with the analog computer art since 1948, his education, experience and responsibilities in the field, together with awards received, inventions made and articles published by him, qualify Warshawsky as a person of more than ordinary skill in the art (Tr. 610-615, 678-682, 684, 685, 743-745, 2033).

E3. Warshawsky's analog computer facility at WADC started in 1948 with a relatively small 16 amplifier machine (Tr. 616) and grew thereafter so that by 1952 or 1953 the laboratory had a total system complement of 128 amplifiers as well as additional non-linear equipment (Tr. 618). The equipment at WADC as of 1954 also included a Goodyear L3 (GEDA) machine (Tr. 722, 727 and 787).

E4. In 1951, a study was initiated which led to an Air Force decision to materially increase the size of the WADC facility. Initially, RCA was awarded the contract to build the new computer (Tr. 639, 640). In 1954 responsibility for the procurement was transferred to Warshawsky and after unsuccessful attempts to correct what he regarded as misdirected efforts, Warshawsky recommended that the RCA contract be terminated and that a fresh approach be taken to the procurement problem.

E5. Although Warshawsky's group had acquired five or six years experience in the analog computer field and was reasonably current on the state of the art in 1954, the

enormous size of the contemplated new computer dictated a call for help from outside experts in the field including computer manufacturers and users of large computers. In the words of Warshawsky, the contemplated WADC computer was to be "four times as large as anything we possessed" and "We did not know all the answers * * *" (Tr. 641).

E6. Accordingly, on July 6, 1954, WADC sent a letter (Px 19) to all the large analog computer manufacturers inviting their engineering talent to meet with Warshawsky to propose ideas and specifications for the new computer with a specific request that proprietary items be designated. The WADC letter specifically called attention to the need for a better approach to checking the validity of solutions produced by the computers (Tr. 642-644).

> "Another consideration in a computer of the size envisioned is the problem of validity of solutions obtained. Such things as minimizing human and machine errors should be considered. * * * Means of running fast check solutions should also receive attention" (Px 19, Tr. 644, 645).

E7. The WADC letter was sent to plaintiff Reeves, defendant Beckman, Electronic Associates, Inc. (EAI), Goodyear, RCA, Mid-Century Instruments and General Electric (Tr. 643, 644). Although the WADC letter was dated in July 1954, R.D. McCoy of Reeves learned of the matter on June 14, 1954 during a meeting with Warshawsky, and began preparation of his ideas and proposals prior to actual receipt of the WADC letter (Tr. 2024-2027).

Findings of Fact

E8. In response to the WADC letter, technical personnel from most of these companies met with Warshawsky and offered various proposals pertaining to the problem of checking (Tr. 645-650). R.D. McCoy, L. Bauer and C.B. Dewey representing Reeves visited WADC on August 18, 1954 and September 8, 1954. During July personnel from General Electric visited Warshawsky's installation followed by a Goodyear representative in August. R.R. Favreau, H. Hamer and J.D. Kennedy of Electronic Associates, Inc. (EAI) visited with Warshawsky in September of 1954 and J.L. Hussey, L. Cahn and H. Martinez of Beckman met with Warshawsky in September 1954; representatives of Mid-Century did the same in October 1954 (Tr. 645-651, Px 25).

E9. In the course of preparing the new computer specification, Warshawsky and his associates made trips to various installations including Lockheed Aircraft, Douglas Aircraft, Convair of San Diego, Cal Tech, Northrup and Bendix (Px 25).

E10. Various checking proposals were received by Warshawsky, but most of them were essentially the same as the previously known methods. One exception was the Beckman proposal for verifying voltages in the computer setup which Warshawsky found "intriguing" but the effectiveness of which he could not understand (Tr. 646, 647). The significant exception was the Reeves proposal which described the Problem Check arrangement (Tr. 646-648).

E11. The patented Problem Check was conceived by McCoy during July 1954 (Tr. 2020; Px 426) and was soon

thereafter disclosed to others within the Reeves company as is established by the deposition testimony of McCoy (Dx NG), Bauer (Dx NE) and Loveman (Dx NF) and an internal memorandum prepared by McCoy and dated September 2, 1954 (Px 427).

E12. The Problem Check arrangement was disclosed to Warshawsky by Reeves' personnel McCoy, Bauer and Dewey during the visit of August 18, 1954, and a description of Problem Check written by Bauer and dated August 16, 1954 (Px 88) was given to Warshawsky during the visit (Tr. 1943-1948, 2026-2032; Bauer Dep. (Dx NE), pp. 38, 39, 44, 46, 73, 74).

E13. A further description, dated September 7, 1954 (Px 23), was left with Warshawsky during the subsequent visit on September 8, 1954 (Tr. 651-654).

E14. Warshawsky immediately recognized the value of McCoy's Problem Check. When asked to describe his reaction to the Problem Check proposal, Warshawsky testified:

> "Well, I suppose it is the reaction that many people have had to it. Our own was that we saw the potential of it almost immediately. We were intrigued by its simplicity. I guess we also wondered why didn't we think of this ourselves" (Tr. 647).

E15. None of the other proposals submitted to Warshawsky (Px 20—Goodyear; Px 21—Beckman; Px 22—Mid-Century; Px 24 and Px 32—Electronic Associates,

Inc.) suggested anything like the McCoy Problem Check technique (Tr. 654, 655).

E16. Warshawsky soon thereafter adopted the Problem Check proposal and incorporated it in the specification for the new computer (Purchase Request 131, Px 26). This WADC specification was sent to the known analog computer manufacturers including plaintiff Reeves, defendant Beckman, EAI, RCA, Mid-Century and Goodyear with an invitation for them to bid thereon (Tr. 655-665).

E17. The WADC specification called for the addition of a new mode of computer operation called "Problem Check" (Tr. 662). The specification went on to describe one circuit arrangement for implementing Problem Check pointing out how the measurement of the initial value of the derivative would be accomplished (Tr. 662, Px 26) and characterizing the technique as a "powerful check".

E18. Plaintiff Reeves, defendant Beckman, EAI and RCA submitted bids in response to the Purchase Request, (Tr. 665), all of which were evaluated by Warshawsky (Px 27, 28, 29, 30, 31, 410, Tr. 671). EAI proposed a Problem Check arrangement (Px 27) which was identical in principle and object to the original Problem Check specification and provided for measurement of the initial derivative as called for in the specifications, but which utilized a circuit arrangement differing in some structural details from that described in the Purchase Request (Tr. 665-670). The Beckman response proposed Problem Check as well (Px 28).

Findings of Fact

E19. Warshawsky found the EAI form of Problem Check to have certain advantages over the Reeves' form in that it required less equipment, particularly potentiometers. However, Warshawsky later came to realize that the additional potentiometers proved to be a virtue worthy of the extra cost (Tr. 676-677).

E20. After evaluating the proposals, the WADC contract was awarded to Reeves and the WADC computer with Problem Check was finally delivered in 1958 (Tr. 677, 678).

E21. Warshawsky's evaluation of Problem Check both before delivery and after experience with it is indicative of the accomplishments of the Problem Check invention. In a paper delivered at a computer meeting in Brussels, Belgium in September of 1955 (Px 371), Warshawsky characterized Problem Check as one of the "unique and definite advances in the art" (Tr. 679, Px 371, p. 89). After noting that "means for checking the validity of solutions obtained on present computers are, to put it mildly, ineffective and time-consuming" and after noting other disadvantages of prior checking techniques, Warshawsky advised his audience that "what promises to be a very efficient checking scheme has been developed by Reeves Instrument people and is given the name of 'Problem Check'" (Tr. 681).

E22. In June of 1959 after receiving and operating the Reeves' machine, Warshawsky delivered a paper (Px 375) to a Simulation Council meeting. Warshawsky in effect

reviewed the entire story of Problem Check, reminded his audience of the state of the art prior to the development of the invention and then went on to describe how the Problem Check technique advanced the state of the art and cured prior art deficiencies. That paper written by a person not associated with an interested party and before this suit was initiated is particularly instructive and probative on the question of the nature of the invention, its relationship to prior art practices and deficiencies, and its accomplishments. It also helps to avoid the danger of slipping into hindsight. Excerpts from that paper are as follows:

> "Now, let's get down to the business at hand and that is to tell you about the unique operational features of our computer—why they came into being—how they are used—and our present evaluation of their worth based on our limited experience with them."
>
> • • •
>
> "Perhaps the best way to introduce the subject of why these features came into being would be to recall the situation existing in 1954 and earlier as regards the state of the analog computer art."
>
> • • •
>
> "Let's look at the less happy side of the picture at the time we were given the assignment of specifying a computer capable of handling three-dimensional simulations of air weapons.
>
> "A big problem (about 80 amplifiers) would come in and I'd turn it over to one or two of my top people to work on—I was an executive even then. After kicking it around awhile they'd come up with a wiring diagram —they'd wire up the four plug boards—check the wiring by having somebody trace each wire and call it

back to his partner holding the schematic—put the boards on the machine—and watch the overload lights come on. Eventually, because we had some real good people—the cause of all the overloads would be found. This could take from an hour to a week and averaged about three days."

* * *

"When the overload lights and wailing servos were taken care of we started recording results. It was an extremely rare problem which came in with a check solution for us to compare our solutions with. We had a few tricks with which Johnson fills up several pages of his book, such as decoupling our second order systems and checking natural frequencies and damping ratios. Of course, we never could be real sure that patching in the cords to couple these loops again resulted in the proper behavior of the coupled system. When we had bomb trajectories to obtain, we would first remove the drag term and obtain a good check—which I am going to describe later. This was called initial condition check, wherein we assigned arbitrary values as integrator initial conditions and checked voltages throughout the rest of the setup against desk-calculated values. We had to remember to restore the proper initial condition voltages to our integrators.

"When it came right down to it, the check most often used was that if the results looked reasonable they were turned out as being okay. Our batting average must have been pretty high since our customers kept coming back—with new problems, that is. During those years of growth and trying to establish ourselves in this computing business, all sorts of clever baling wire tricks were developed to try to increase our feeling of confidence in our results. We knew how to check to see if the rates were too high for our servos

to follow—but going through all the equations to calculate the coefficients corresponding to a change in time scale and then changing the pots was too time-consuming and fraught with danger of error to consider doing very often."

"We knew that visual patchboard checking was not a very certain method—certainly useless for finding internally broken cords. And in spite of eternal vigilance—patchcords would somehow disappear from boards."

"Remember setting pots using the servo as the voltmeter and wondering if you removed the loading resistor on the followup pot? Remember the plug boards with those hanging resistors and capacitators and those switches you forgot to turn on? And do you remember those few occasions when you hung a scope on the machine and saw all that noise?"

"I could go on and on but you old-timers in this business know all these things—and newcomers don't have a real appreciation for them. Suffice it to say, the analog computers of 1954 left much to be desired—especially if you were seriously considering building one five times as large."

* * *

"Solving the problem you think you are solving really covers a multitude of possible trouble spots. Just think of some of the ways we can insert on the machine a problem other than the one we were asked to solve:

"We could:

a. Make an error in the mathematical manipulations to the problem as originally supplied.

b. Make an error in the schematic diagram.

c. Make an error in wiring the board.

d. Use a non or malfunctioning component.

e. Set a scale factor pot wrong.

f. Set a function in wrong.

g. Forget to turn on a switch."

"Any one of these very simple causes could result in a right solution to a wrong problem. Preventing these is practically impossible for as Steig puts it so succinctly—'People are no damned good.'—Our effort was to make the detection of these difficulties conveniently possible so that they could be rectified. Problem Check, the Patchboard Verifier, automatically set DFG's, in fact the whole Flexowriter Systems falls in the overall category of insuring that what is on the computer is the problem you want to solve. It is quite true that these features provide certain operator conveniences that might appear to be luxuries. This is merely a byproduct to their more important purpose."

• • •

"Let us now move on to Problem Check. This is a very powerful static test that tells you almost everything you need to know about the problem setup on the computer—all the way back to the original equations. The scheme is basically very simple and doesn't involve much additional hardware. As I indicated earlier, its predecessor was Initial Condition Check which we used in the past. Before it can be applied some desk calculator work must be done too."

• • •

"Thus Problem Check gives all the advantages of Initial Condition Check plus a checkout of the integrators themselves—and it is applied without disturbing the computer setup in any way."

• • •

"If any question exists as to the practicality of some of the other features of our machine, Problem Check has proven itself very forcefully in every problem we've handled since opening for business. I would go so far as to say that any large analog computer absolutely requires this feature or its equivalent."

E23. These excerpts from Warshawsky's paper fairly summarize the state of the art prior to the making of the invention and particularly the incomplete character of prior art checks and their aggravation of the human error problem. They also demonstrate the accomplishments of Problem Check in curing the prior art deficiencies.

E24. Problem Check has been used at the Wright Field facility from 1959 to the present (Tr. 699) on every problem solved there. That facility handles an average of approximately 80 problems per year involving an average problem size of approximately 200 to 300 amplifiers (Tr. 700, 701).

E25. It is true as defendant contends that Warshawsky later found it desirable to modify the Reeves Problem Check illustratively disclosed in the patent in suit because of a loading problem which created an inconvenience. That modification involved combining certain circuit features of the original Reeves' form of Problem Check with certain circuit features of the Electronic Associates adaptation of Problem Check. The modified Problem Check at WADC is the same as the original form as far as basic mode of operation and purpose are concerned and it still provides a non-disturbing measurement of the initial derivative (Tr. 703-713).

Findings of Fact

E26. Apart from its continuous use since 1959 at Wright Field, Warshawsky pointed out that the utility of Problem Check has increased with the advent of the addition of digital computing equipment to the analog computer systems (Tr. 706).

E27. Following disclosures to Warshawsky in August and September of 1954, and prior to being awarded the WADC contract, Reeves undertook to commercialize Problem Check in its new REAC 400 computer. Sales trips were made by B. Loveman of Reeves to various installations around the country between the summer of 1954 and April 1955 promoting the REAC 400 computer including Problem Check. An article describing Problem Check was published in "Control Engineering" of July 1955 (Dx AJ, Tr. 1938, 1939). Construction of the first REAC 400 computer with Problem Check commenced in November 1954 and the machine was publicly displayed and the operation of Problem Check demonstrated at the March 1955 IRE show (Tr. 2021, 2033-2043; Dx NF, pp. 76, 77; Px 127, 128, 143, 144, 301, 306-308, 438). Ultimately, the bulk of all REAC 400 computers included Problem Check (Admission 40).

Reaction of Electronic Associates, Inc. to Problem Check

E28. When Warshawsky first called for assistance, EAI responded by sending Messrs. Favreau, Hamer and Kennedy to Wright Field. They conferred with Warshawsky and left a written proposal with him, one section of which was devoted to the problem of checking (Px 32).

E29. Their proposed solution to the problem, which they considered valuable enough to be termed "proprietary information", called for the use of a standard set of problems which would be substituted for the actual problem setup in order to exercise all of the computer components (Px 32). This proposal was essentially "a rehash" of then known checking methods and was rejected by Warshawsky (Tr. 646).

E30. After receiving the Wright Field specification PR 131 (Px 26) and having learned of the Reeves' Problem Check, EAI dropped its "proprietary" proposal and undertook to exploit the Reeves' technique (Tr. 1378, 1380). Favreau, referring to EAI's Problem Check, said at the time this "looks real good to me" (Dx EB). On cross-examination at trial, EAI's Chief Engineer Massell admitted that the EAI Problem Check represented "an attempt to retain the advantages of the Reeves' Problem Check and yet effect improvements" (Tr. 1380).

E31. In its original form, the EAI version of Problem Check lacked the feature of non-disturbing test voltages for integrators having zero initial conditions. This provision has sometimes been referred to as the "false IC" feature and is a part of the Problem Check arrangement. Later, however, that omission was corrected and the false IC arrangement was included in the EAI checking system. From its first attempted implementation of Problem Check, however, EAI provided the circuit configuration necessary to measure the signals representing the initial value of the derivative of each integrator. EAI's early literature de-

scribing this first version of Problem Check identified these signals as being "of prime importance" and noted that prior EAI checking schemes did not measure them (Dx EC).

E32. The complete EAI Problem Check arrangement including false IC and the derivative measuring circuit is embodied in the EAI 231R machine which was first exhibited in December of 1957 (Tr. 1398). Substantially all of the large general purpose analog computers manufactured and sold by EAI since then have included this same checking system (Admission 51) and statements in EAI literature and other documents concerning its virtues is evidence of the high regard with which it is held by that manufacturer (Dx EB, EC; Px 84, 417).

Beckman Reaction to Problem Check

E33. Defendant Beckman also promptly undertook to exploit Problem Check. Beckman engineer Alan MacLane testified by stipulation that he designed a "simplified version" of Reeves' Problem Check prior to January of 1956, probably not earlier than October of 1955, and that this design was made in the light of the Reeves' Problem Check system (Tr. 409-412, 414; Px 34, 45, 57, 74, 396).

E34. That original Beckman version ultimately formed the basis for the static checking technique incorporated in the Beckman 1100 computer first marketed in 1956-57. Most of the activities involving the 1100 machine were phased out prior to the issuance of the patent in suit. However, statements made by defendant concerning the

1100 static check are relevant in that they represent the defendant's own appraisal of Problem Check well before this litigation was initiated.

E35. In a group of Beckman advertisements involving the 1100 computer, in inter-office correspondence among defendant's employees, and in operating manuals supplied to customers of the 1100 machine, the virtues of Problem Check were extolled. It was referred to as a "new concept" (Tr. 421), and was credited with providing a complete and rapid check which eliminated prior art deficiencies. It was heralded as "an extremely powerful (check) * * * that * * * confirms all wiring to all computer elements and the correctness of all attenuator settings" (Tr. 423).*

E36. Ultimately, the 1100 computer was replaced by the Beckman 2100 and 2200 series computers which embodied a Derivative Check system which is substantially identical to the static Derivative Check arrangement which had previously appeared in the 231 R computers manufactured by Electronic Associates, Inc. (EAI) (Admission 51 in Pre-Trial Order). As compared to the prior static checking arrangement in the Beckman 1100 computer, the Derivative Check of the 2100 and 2200 computers differs in circuit details but is the same in substance as is essentially admitted in Beckman literature directed to both the 1100 and 2100 computers (Px 38).

E37. Defendant Beckman was aware of the EAI Derivative Check arrangement prior to development of the Beckman 2100 series computer and embodied the EAI Derivative

* See Px 34, pp. 170, 171, Px 45, Px 57, Px 74.

Check system in their 2100 series computer (Tr. 902, 903). It follows that the checking system in the 2100 computer likewise owes its inspiration to McCoy.

F.

Infringement of the Patent in Suit by Defendant Beckman

F1. Although an optional feature, 90% of the Beckman 2100 computers included the accused static checking system which defendant has called "Derivative Check" (Px 5). This same static checking system was standard in all of the later Beckman 2200 computers. In some later models of the Beckman computers this static checking system is called by other names such as "Integrand Check" and is incorporated as part of a more elaborate checking system called "Anacheck". However, the structure and operation of the static checking system is substantially the same in all the Beckman 2100 and 2200 computers (Admission 34; Tr. 239) and is referred to herein simply as the "Derivative Check" system.

F2. In the Beckman Derivative Check system the integrator amplifier is disabled or rendered ineffective by means of a resistor connected across the integrator amplifier in parallel with the integrating capacitor (Tr. 529, 530).

F3. In the Beckman Derivative Check system known test voltages of preselected values appear in place of each of the normal integrator output voltages. This is accomplished by connecting the reference voltage supply or the false IC voltage supply through patching connections made

by the operator to potentiometers which in turn are "patched" to the "IC" terminals of the initial condition networks of the integrators. When the integrator is disabled by connecting a known resistor across the amplifier, the integrator forms an inverter and therefore the magnitude of the signal appearing at the integrator amplifier output (except for sign) is identical to the magnitude of the signal applied to the initial condition network (Tr. 257, 259, 260, 262).

F4. In the Beckman Derivative Check system, all special test voltages, namely those obtained from the "false IC" voltage supply for the purpose of Derivative Check (sometimes referred to as "false IC" voltages) are obtained without disturbing the computer setup and the computer cannot be placed in the "compute" or "operate" mode unless such special test voltages are first removed (Px 9, page 86; Tr. 372-373).

F5. As is the case with most analog computers, when the Beckman 2100 and 2200 computers are set up to solve a typical problem, the computation signals flow in a complex maze of closed computation loops. Typically, each such closed loop passes through at least one integrator.

F6. In the Beckman Derivative Check system, the signal path passing through each of the integrators is broken so that each of the computation loops is opened at the integrator, this being achieved by disconnecting the summing junction of the input network from the integrator amplifier (Tr. 253, 529).

Findings of Fact

F7. In the Beckman Derivative Check system, known test voltages are applied to and flow through all of the opened computation loops, through all the computation elements of the computer involved in the particular problem solution, and emerge at the integrator input circuits to provide signals which form the initial derivatives appearing at the summing junctions of the integrators (Tr. 263, 530).

F8. In the Beckman Derivative Check system, the initial values of the derivatives are measured by selectively connecting a negative feedback amplifier to the integrator input resistors at their respective summing junctions (Tr. 255, 257, 260-262).

F9. In the Beckman Derivative Check system, the initial derivative values are measured without disturbing any of the patching connections or potentiometer settings forming part of the problem setup (Tr. 522).

F10. The Beckman Derivative Check system differs in some circuit details from the static checking system disclosed as the illustrative embodiment of the patent in suit but, in substance, the two systems are the same and operate in substantially the same way to achieve the same result (Tr. 265-266; see also Tr. 259-265, 329, 360, 391, 526, 531, 572, 581, 601).

F11. Claim 13 is typical of the asserted claims and literally and substantively describes the Derivative Check system embodied in the Beckman 2100 and 2200 computers. Defendant failed to seriously challenge the demonstration

of infringement and did not introduce any significant evidence to the contrary.

F12. Claim 13 of the patent in suit, broken down into sections a-h for convenience, is as follows:

> (a) Apparatus for testing an analog computer including at least one integrating circuit, * * *
>
> (b) * * * said integrating circuit having an input coupled to first terminal means of the remaining elements of the computer and an output coupled to second terminal means of the remaining elements of the computer to form a closed-loop system, the input of said integrating circuit including a series input resistor, * * *
>
> (c) * * * comprising in combination, means including switching means coupled to said integrating circuit, * * *
>
> (d) * * * a source of known voltage coupled to said switching means, * * *
>
> (e) * * * said switching means rendering said integrating circuit ineffective * * *
>
> (f) * * * and supplying a known voltage to said second terminal means of the computer, * * *
>
> (g) * * * said known voltage being translated through the remaining elements of the computer to the series input resistor of said integrating circuit, * * *
>
> (h) * * * and measuring means including amplifier means coupled to said series input resistor for measuring the response of the remaining elements of the computer to said known voltage.

Findings of Fact

F13. Sections (a) and (b) of claim 13 are the preamble portion of the claim which sets forth the environment or setting as is typically found in a general purpose analog computer. This preamble describes a general purpose analog computer including an "integrating circuit" and a "closed-loop system," the latter signifying that the computer patching and problem setup has been completed by the computer operator as part of the environment in which the invention is to operate (Tr. 510-513). The environment, as set forth in sections (a) and (b) of claim 13, is found to exist in Beckman computers embodying the Derivative Check system (Tr. 510-513 and 521-522).

F14. Sections (c), (d), (e) and (f) of claim 13 set forth the circuit changes in the integrator which are necessary to set up the test conditions which must exist for performance of the nondisturbing static check as taught in the patent. The "switching means" within the integrator render the integrating circuit "ineffective" as can be achieved by connecting a resistor across the integrator amplifier. The "switching means" also provide a "known voltage" as a test signal in place of the amplifier of the integrator which has been rendered ineffective and functions as an inverter. Each of the circuit configurations recited in sections (c), (d), (e) and (f) of claim 13 are found to exist in the Beckman computers when the Derivative Check circuitry therein is activated to place the computer in the Derivative Check mode (Tr. 514-517 and 523-524).

Findings of Fact

F15. Section (g) of claim 13 describes what happens as a result of the circuit changes set forth in sections (c) to (f) of the claim. In typical loops the test voltages emerge from the integrators, are translated through other computing elements and resultant signals eventually appear at "the series input resistor," as described by clause (g). The test voltages are "translated" in this fashion in the Beckman computers when the Derivative Check and false IC circuitry therein are activated (Tr. 518 and 525).

F16. Section (h) of claim 13 describes the circuit configuration whereby the initial value of the derivative is measured (Tr. 520). The claim specifies that this configuration is established by connecting an amplifier to the input resistor of the integrator. This language describes the coupling between the input resistor and the measuring amplifier which as shown in the patent occurs at the summing junction of the integrator (Tr. 215-217, 240, 241). The Beckman Derivative Check system includes such a measuring amplifier which is connected to the summing junction (Tr. 257) and functions in the same manner as the measuring amplifier shown in the patent to achieve the same result (Tr. 260, 357, 526, 581, Admission 35). By operating the Derivative Check system, the amplifier is selectively coupled to the integrator input resistors as defined in the claim to thereby measure the initial value of the derivative appearing at the summing junction in the same way as is done in the illustrative circuit of the patent in suit (ibid).

Findings of Fact

F17. All elements of claim 13, both literally and in substance, are found in Beckman computers which include the Derivative Check system (Tr. 521).

F18. Claims 7 and 8 cover the same territory as claim 13 (Tr. 535), claim 7 being the broadest in scope of the three claims and claim 8 being of intermediate scope.

F19. Claim 7 broken down into separate sections for convenience, is as follows:

(a) In an analog computer including an integrating circuit, * * *

(b) * * * said integrating circuit having input and output terminals coupled to the remaining elements of said analog computer for forming a closed-loop feedback system, * * *

(c) * * * the combination for testing the analog computer system comprising switching means coupled to said integrating circuit, said switching means opening the loop of the feedback system, * * *

(d) * * * and rendering said integrating circuit ineffective, * * *

(e) * * * means supplying a fixed voltage to the opened-loop system, * * *

(f) * * * said fixed voltage being translated through said opened-loop system to the input of said integrating circuit, * * *

(g) * * * and means coupled to the opened-loop system for measuring the voltage appearing at the input of said integrating circuit.

Findings of Fact

F20. Sections (a) and (b) of claim 7 set forth the environment as found in a typical general purpose analog computer when all the patch connections and settings have been completed to form the "closed-loop feedback system" (Tr. 528-529); sections (c), (d) and (e) set forth the integrator circuit changes required for performance of the non-disturbing static check taught in the patent which are (1) to open the loop, (2) render the integrator "ineffective" and (3) supply the test voltage (Tr. 529-530); section (f) recites the results which follow from the conditions established in sections (c), (d) and (e) (Tr. 530); and section (g) refers to the "means * * * for measuring the voltage appearing at the input of said integrating circuit", which means, construed in the light of the specification, describe the initial derivative measuring amplifier and meter (Tr. 533-534). All of the elements of claim 7, both literally and in substance, are found in the Beckman computers which include the Derivative Check system (Tr. 531-543).

F21. Claim 8 broken down into separate sections, is as follows:

> (a) In an analog computer including an integrating circuit having an amplifier with input and output terminals and a common terminal, * * *
>
> (b) * * * said integrating circuit including condenser means coupled between the input and output terminals of said amplifier and further including an input resistor coupled in series with the input of said amplifier, * * *
>
> (c) * * * said integrating circuit being coupled to the remaining elements of said analog computer for forming a closed-loop feedback system, * * *

(d) * * * the combination for testing the analog computer system comprising shunt resistor means, * * *

(e) * * * switching means coupled to said integrating circuit and said shunt resistor means, said switching means opening the loop of the feedback system and coupling said shunt resistor means across said condenser means, * * *

(f) * * * means supplying a fixed voltage to the opened-loop system, * * *

(g) * * * said fixed voltage being translated through said opened-loop system to the input of said integrating circuit, * * *

(h) * * * and means coupled to the opened-loop system for measuring the voltage appearing between the input terminal of said input resistor and said common terminal.

F22. Sections (a), (b) and (c) of claim 8 set forth the environment limited specifically to electronic analog computers (i.e. computers including a "condenser" as an integrating element), where the setup for the solution of a problem has been completed to form a "closed-loop feedback system" (Tr. 594-597); sections (d), (e) and (f) recite the required integrator circuit changes which render the integrator ineffective through the use of a "shunt resistor", open the loop of the feedback system, and supply a "fixed voltage" to the "opened-loop system" as a test signal; section (g) describes the result of the circuit changes recited in sections (d), (e) and (f) where the test voltages are coupled to other components of the computer system

and are in some manner transferred so that they effect the input of the integrating circuit being thereby "translated through said opened-loop system (Tr. 599-600); and section (h) refers to the measurement means which function to measure the initial derivative (Tr. 600-601). The language of claim 8 clearly describes what is found in Beckman computers which include the Derivative Check system (Tr. 594-601).

F23. Since issuance of the patent in suit, defendant Beckman has operated and used the Derivative Check system as described in its applicable computer manuals (Admission 9, Tr. 236-237) embodied in its 2100 and 2200 computers which uses employ the apparatus in the manner described by claims 7, 8 and 13.

F24. Since issuance of the patent in suit, defendant Beckman has furnished instruction manuals to customers of its 2100 and 2200 series computers describing the Derivative Check system and advocating its use and operation in the manner therein described (Px 5-9, 14, 16, 17, 320; Tr. 236), which uses employ the apparatus described in claims 7, 8 and 13.

F25. Since issuance of the patent in suit, customers of defendant Beckman have used and operated the Derivative Check system in the Beckman 2100 and 2200 in the manner described in appropriate manuals (Admission 10, Tr. 237), and in so doing employ the apparatus described by claims 7, 8 and 13.

Findings of Fact

F26. Plaintiffs gave notice to defendant of the infringement of the patent in suit during February of 1961 (Admission 2 of Pre-Trial Order).

F27. As delivered by defendant Beckman to its customers, all of the components of the 2100 and 2200 Derivative Check systems are wired into the computer but certain interconnections, which depend on the problem to be solved, are left to the user to complete for the purpose of performing the check.

G.

Scope and Content of the Prior Art, the Level of Skill in the Art, and Differences Between the Prior Art and the Invention

G1. Defendant contends that the patent is invalid under the provisions of 35 U.S.C. 102 and 103. Each of the prior art checks adduced at the trial differed in one or more material respects from the claimed invention and the defense of invalidity for lack of patentable invention is accordingly limited to the question propounded by section 103 of whether:

> "* * * the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains." (35 U.S.C. 103)

Findings of Fact

G2. The following prior art was asserted at the trial:

(a) the IC check;

(b) the MIT checks;

(c) the Trembath Thesis;

(d) the Jatras Thesis;

(e) the Wilder/Martin check;

(f) the Mackey/LTV check;

(g) the Favreau / Hughes — patchcord pulling check;

(h) the Favreau/Hughes—special switch check;

(i) the Ulrick/NOL—patchcord pulling check;

(j) the Ulrick/NOL—special switch check;

(k) the Hussey patchcord-pulling, resistor-plugging check;

(l) the Thomas patent;

(m) the Hunt component test;

(n) the Cook check;

(o) the Sanders check.

G3. An understanding of these checks and their significance in relation to the patented Problem Check system is aided by a description of the general conditions characterizing the state of the art prior to the making of the invention including the extent to which the workers in the art devoted attention to the problem, the progress they made toward obtaining a solution, and the level of ordinary skill in the art. Accordingly, findings on these points will be included.

Findings of Fact

(a) The IC Check

G4. In the operation of integrators in analog computers, voltages are established to simulate initial conditions. These are fed into the integrator circuits while the machine is in a mode known as "Reset" or "Initial Condition" or simply "IC". In the Reset condition the initial condition voltages are established on the integrating capacitors to define the starting point for integration (Tr. 167-171, 188-203; Px 367, 368).

G5. These initial condition (IC) voltages were used as test voltages very early in the use of analog computers. In Dr. Korn's 1952 textbook "Electronic Analog Computers" a prior art static check is described which makes use of these voltages as sources of test signals. The computer is placed in the "Reset" mode, and the effect of the IC voltage is measured by measuring the resultant voltages appearing at the outputs of the various computing elements connected to the integrators (Tr. 188-192; Dx CK, page 326).

In the IC check, the integrator is disabled or rendered ineffective by means of a resistor connected across the integrator amplifier in parallel with the integrating capacitor.

Known test voltages of preselected values are obtained from the problem initial condition voltages of those integrators which have suitable IC's. In the case of the other integrators, special IC voltages were generated for the purpose of the test. These problem and special IC voltages

appear in place of each of the normal integrator output voltages. This is accomplished by connecting the reference voltage supply through patching connections made by the operator through potentiometers which in turn are "patched" to the IC terminals of the initial condition networks of the integrators. When the integrator is disabled by connecting a known resistor across the amplifier, the integrator forms an inverter and therefore the magnitude of the signal appearing at the integrator amplifier output is identical to the magnitude of the signal applied to the initial condition network (Px 368; Tr. 188-193).

In the IC check, all special test voltages inserted for the purpose of making the check require a disturbance of the computer setup and the operator must remember to remove them from the circuit before the computer is placed in the "compute" or "operate" mode (Tr. 192-193; Px 367; Tr. 248-251).

In the IC check, the signal path passing through each of the integrators is broken so that each of the computation loop is opened at the integrator, this being achieved by disconnecting the summing junction of the input network from the integrator amplifier (Tr. 167-169).

In the IC check, known test voltages are applied to and flow through all of the opened computational loops through all the computation elements of the computer involved in the particular problem solution. Voltages appear at the integrator input terminals at the patchbay. However, the summing junction is directly grounded or is floating, de-

pending on the machine, so that no initial derivative signals exist (Tr. 188-194, 198, 199, 277, 278, 297).

In the IC check, the voltages appearing at the outputs of the computing elements feeding the integrators are measured. Accordingly, the IC check did not verify the operability of the patchcord connections to the integrators, that the cords were in the right patch holes and properly seated therein, that the patch bay terminals were operative (ibid.), that the circuit from the terminals to the summing networks was operable, and that the summing network of each integrator was operable (Tr. 193, 194, 210, 244-248).

G6. The IC check suffered from both major defects mentioned previously. The check was incomplete in that it failed to check the input circuits of the integrators or the patch connections thereto (Tr. 192-194, 243-248), but did check all other connections and components. However, to check a significant number of these connections and components requires special IC's thereby causing a disturbance of the problem set-up and an aggravation of the human error problem (Tr. 193, 248-251). The measurement of the initial value of the derivative is not provided by the IC check (Tr. 210, 1632, 1633, 1643; Dx OK-1). It follows that this check does not suggest the concept of making such a derivative measurement without disturbing the problem setup.

G7. The prior art IC check and its shortcomings were acknowledged and described in the original specification of the patent in suit (Tr. 208-210). After describing the

Initial Condition mode of the illustrated computer setup, the patent notes that:

> "The outputs of the various components may be calculated and compared with the actual values obtained from the computer under such initial conditions, but this does not provide a complete check because the integrator connections, inputs and performance are not verified" (Column 3, lines 15-19).

G8. The IC check as reported in the Korn text originated at the RAND installation in 1948 or 1949. Gunning and Mengel of that facility undertook modifications of their computer with a view towards improving it in various areas including the checking area (Tr. 1630, 1631). Defendant relies on this modified computer as prior art but nothing more than the standard IC check has been established by this machine. Defendant's expert Dr. Korn described both Gunning and Mengel as being high-caliber engineers and in the case of Gunning, "more so" (Tr. 1631, 1632). The fact that the best these engineers could devise was the IC check evidences the non-obvious character of McCoy's Problem Check arrangement.

G9. The IC check as described in the Korn text (Exhibit CK) was cited by the Patent Office Examiner during the prosecution of the patent in suit and, after due consideration, the claims of the patent were held to define an invention patentably different from the IC check (Dx CF, pp. 28, 29, 35, 36, 44, 45, 47-50). (A dynamic derivative measurement technique, Px 231, page 149, was also cited by the Examiner.)

Findings of Fact

G10. Defendant has acknowledged the basic deficiencies of the prior art IC check. In a discussion of the advantages and operation of the Derivative Check systems of the 2100 and 2200 computers, C.H. Single of Beckman's engineering staff wrote:

> "The IC check suffers from two major loopholes. First, some initial conditions are usually zero in the typical problem, which means that it is impossible to trace the effect of this voltage through the following computer elements, that is, a missing patchcord, grounded patchcord, incorrect gain or incorrect coefficient potentiometer cannot be detected with zero volts applied. Second, the input to each integrator is disconnected and there is no indication of this input available in the standard analog computer. To overcome these two major loopholes, a False IC feature has been incorporated in the 2100 Series Computer and a Derivative Check module is available as a recommended option" (Px 38, page 6).

(b-d) Checking Procedures Involving the MIT Facility

G11. Construction of the MIT facility was started in 1945 and computations commenced in 1948 (Px 231, page 117; Dx GE). The MIT computer was of the electromechanical rather than the electronic type. In particular the integrators in the MIT computer embodied motors, the shafts of which rotated to carry out integration processes (Px 231, page 118; Dx GG, pages 11-16; MN, page 316; MZ 8, 9, 10; Tr. 856, 857, 1464, 1495-1598). By contrast, in the electronic integrator which is found in all modern analog computers and which is the type of integrator described in the patent in suit, integration is accomplished

through the action of an electrical capacitor and an operational amplifier. No motor is involved (Tr. 97, 98, 1597-A).

G12. The electronic integrator also has provisions for summing a group of separate inputs whereas the MIT electromechanical integrator is limited to a single input (Tr. 97, 102, 1005, 1007, 2106). Accordingly, to integrate the sum of several signals it is necessary in the MIT system to provide a separate summing amplifier the output of which feeds the integrator (Tr. 1007-1010). Both the electronic and the electromechanical integrators have summing junctions at which the initial value of the derivative appears (Tr. 1597, 2074, 2075). In both types of integrators there are components which precede the summing junction. In the case of the electronic integrator the summing junction signal is supplied from a group of parallel resistances the upstream terminations of which are connected to the patch bay for receiving signals from the computing elements which precede the integrator (Tr. 102, 103).

G13. In the case of the prior art electromechanical integrator at MIT, a signal is fed to the summing junction by way of a terminal known as the "integrand input". From this integrand input terminal the signal must pass through a switching network and two adjustable resistances before it reaches the summing junction where the initial derivative appears (Tr. 2072, 2076).

G14. Checking procedures were of primary interest to the engineers and scientists at the MIT facility and tech-

niques were developed to detect frequently occurring human errors and errors not apparent in the answers supplied by the machine. A checking technique which avoided disturbance of the computer setup was also sought (Px 231; Dx MN, GF, GG, GN, MK, MN, NH). The prior art procedures which evolved as an outgrowth of the MIT work were described in the testimony of Hideo Mori and Stephen Jatras, in the deposition testimony of Professor Seifert (Dx NH), and in printed publications describing the MIT facility and its checking techniques including a thesis by Stephen Jatras (Dx IY), a thesis by N. Trembath (Dx GG) and various articles from professional journals and the like (Dx GF, GN, MK, MN).

G15. So far as static checking of the actual machine is concerned, all of these descriptions indicate that a static checking arrangement was devised and practiced at MIT which involved disabling the integrators, opening the loops at the integrators, the use of test voltages and the measurement of resultant voltages at various points including the integrand input terminal which is separated from the summing junction and the true initial derivative by the three adjustable networks previously described (Dx GG, page 65; Dx OK-1; Tr. 1555, 1646). Test voltages were obtained from the integrator outputs by converting the integrators to positioning servos and by rotating the motor shafts to selected positions (Dx GG, page 65; Tr. 1555-1557). The evidence is in conflict as to whether the test output voltages were automatically established so as to avoid the need for disturbance on initial condition settings. The testimony of Mori seems to suggest that these voltages

could be established in an automatic manner (Tr. 1559). On the other hand Jatrås testified that his thesis proposed a checking system which purported to do what Mori claimed was already done, namely, automatically set up the check voltages so that the operator would not have to remember to return them to their proper settings when computation was started (Dx IY, pages 5-7, 18, 22, 23, 26, 61; Tr. 1477).

G16. This conflict need not be resolved since the MIT procedures used on the actual machine, whether instrumented manually or automatically, did not go beyond a measurement of the signal at the "integrand input" terminal (Tr. 1554, 1555). A measurement of this signal failed to check the switching network and adjustable resistances through which the signal must pass before it reaches the summing junction where the initial derivative appears (Tr. 1646, 1647, 2072).

G17. Because the MIT procedures used on the actual machine were limited to a measurement of the signal at the integrand input terminal rather than the summing junction signal, the MIT static check was incomplete, the omission being particularly serious because the three adjustable elements, all subject to human error and capable of an infinite number of settings, were not checked (Tr. 2072, 2075, 2076).

G18. The workers at MIT also devised a duplicate patch panel to avoid disturbing patchcords in making measurements (Tr. 1551, 1563, 1677, 2073). However, this

technique did not cure the failure to check the three adjustable integrator elements (Dx OJ; Tr. 1566, 1567). It also added materially to the complexity of the apparatus (Px 352; Tr. 1567, 1568) and has not been adopted by the industry (Tr. 2073).

G19. These shortcomings in the MIT work are significant on the question of obviousness since the results obtained at MIT were the product of extensive analysis of the problem of checking by highly skilled persons. Trembath in his thesis (Dx GG) reported that:

> "A large amount of effort has been expended in the search for effective means of determining the accuracy of analog computation and for methods of sensing the presence of faulty components in an involved computational setup." (id pages 63 and 64)

The check described by Trembath in his thesis calls for the measurement of the signal at the integrand terminal as previously described and also refers to the use of the duplicate patch panel (Dx GG, pages 64, 65).

G20. A report on checking at the MIT facility, authored by Mathews and entitled "Progress on a Basic Analysis of the Errors in Analogue Computers" (Dx GN), similarly evidences concern with the checking problem. In describing the procedures practiced at MIT, Mathews reported that:

> "An important part of the operating time is spent in finding and locating setup mistakes and faulty components, and the extent of this check-up time depends largely on the operator's skill." (page 7)

The solution described by Mathews is essentially the same integrand measurement at the integrand terminal and the duplicate patch bay technique described by Trembath (Dx GG, pages 27-29).

G21. Professor Seifert, who played a prominent role in the design and operation of the MIT computer, also published a report (Px 231, pages 117 et seq.) on the activities at MIT relating to the checking of the computer. His observations confirm that the MIT personnel devoted considerable attention to the problem of checking:

> "The operational problems which arise in meeting the responsibility of the Simulator to produce as much acceptably accurate and completely reliable data as possible are many. Human errors and component failures must be controlled, setup time must be minimized, accuracy and reliability must be continually checked without using disproportionate amounts of time, and records of the parameters being studied must be complete without being unwieldy and burdensome. * * *" (Px 231, page 117)
>
> * * *
>
> "Human error is not only the most frequent trouble occurring in the operation of a computer but also the most difficult type to combat. One mistake can render many solutions worthless and, what is more alarming, possibly may remain undetected. Elimination of *all* human errors is prohibitive in time and cost because diminishing returns rapidly set in with excessive checking. * * *" (id, page 120)

The MIT checks described by Dr. Seifert in mitigation of this problem are essentially those also described by Trem-

bath and Mathews (Px 231, page 120; Dx NH; Tr. 1683-1686).

G22. The testimony of defendant's witness Jatras is also significant on the question of whether the invention was obvious. He was concerned with the problem of checking. He testified during his direct examination that:

* * *

> "Everybody was concerned about improving the operation of the computer, to get more operating efficiency, and from time to time we would have a rash of problems which would give us some rather poor days. Sometimes we would be out of business for a day or two days while people chased around trying to find out what was wrong with this thing. Frequently what was wrong was so simple that it kind of horrified us to think that you could spend that kind of time because somebody threw a switch wrong. This was kind of on the top of everybody's mind, to try to find, to give a handle on this situation" (Tr. 1460-1461).
>
> "Everybody was continuously trying to find better ways and more efficient ways to insure that the machine was working" (Tr. 1463).

G23. In his search for better and more efficient ways of checking the computer, Jatras studied the problem at length, compiled data on machine failures (Dx GZ) and wrote a comprehensive thesis on the subject (Dx IY). The Jatras thesis is a prior printed publication and evidences a thorough study of the problem of computer checking (sixty-one pages of analysis) and states:

> "The fact that the error may go undetected, however, is exceedingly serious" (page 6) * * *. "Wrong solutions are worse than no solution" (page 35, 36).

The problem of human errors is also recognized (id pages 4-7, 30, 34) as is the need to avoid disturbing the computer setup in the course of making the check (id pages 33, 34). In spite of this impressive analysis of the problem and an exhaustive study thereof, the best that Jatras could do was to propose a signal tracing system which automated the checking procedures theretofore practiced at MIT (Tr. 1479, 1486, 1499-1501). In short Jatras proposed to automate the measurement of the signal at the integrand terminal which, as noted previously, is remote from the vital summing junction and true initial derivative (Dx MZ-10; Tr. 1011, 1012, 1490-1497, 1501, 2073, 2074). While Jatras proposed to establish test voltages without disturbing the computer setup thereby checking a substantial part of the computer without introducing human error problems, his check nevertheless failed to check the three adjustable elements between the integrand signal terminal and the summing junction (Tr. 1015, 1016, 2075). When asked during his redirect examination by counsel for defendant whether it was within the teaching of his thesis to measure the summing junction signal, Jatras responded with an unqualified "No" (Tr. 1512, 1513).

G24. None of the procedures relating to the MIT facility, either practiced or proposed, suggested the measurement of the initial derivative (Tr. 2071-2073) and all were defective in failing to check the adjustable resistances and switches of the integrators.

G25. In principle and in result the MIT procedures were the same as the IC check (Tr. 1645, 1646, 2072).

Findings of Fact

(e) The Wilder/Martin Check

G26. Defendant also contends that the Problem Check invention is anticipated or rendered obvious by the checking procedure described by Betty Lou Wilder of the Martin Company in her deposition testimony (Dx NJ, DQ, DR, DS, DT). To understand the check described by Miss Wilder it should be noted that most electronic integrators are both summers and integrators, that is, they can simultaneously be supplied with a number of input signals which are fed through a group of parallel summing resistors, combined, and then integrated (Tr. 102, 103). In the conventional IC check, measurements would be made, as previously described, of the various voltages appearing at the outputs of the computing elements which feed these summing resistors but would not be made at the summing junctions.

G27. In an effort to overcome this weakness in the IC check, Miss Wilder practiced a technique at Martin in which the signals, otherwise summed in the summing network of the integrator, are independently summed in a separate preceding summing amplifier whose output is then fed to the integrator as a single input thereto (Tr. 2054). This technique tended to reduce the unverified portions of the problem to the single connection to each integrator and the single resistor in each integrator summing network which passed this signal to the summing junction (Tr. 2056, 2057).

G28. However, this improvement was accomplished by sacrificing the summing capabilities of the integrators and

it thereby reduced the effective capacity of the machine (Tr. 2058, 2059, 2061, 2062). In any event it is basically the IC check (Tr. 2059-2061). and has the same shortcomings as the IC check in that it fails to check the patch connections to the integrator or the active input resistor of the integrator (Tr. 2055-2058). It also requires disturbances of the problem setup in order to obtain suitable test voltages, this deficiency being the same as with the conventional IC check (Tr. 1868).

G29. Defendant's attempted application of this prior art technique rests in part upon a semantic nicety. The signal developed in the separate summing amplifier which feeds the integrator is sometimes referred to as an initial derivative signal (Tr. 1868). But it is not a true initial derivative (Tr. 2056). It is rather an assumed initial derivative and can only be equated with the true initial derivative provided the patchcord connection from the separate summing amplifier to each integrator is operable and is in the right hole of the patch bay and provided further that the associated contacts of the patch bay are sound and the summing resistor of the integrator in operating order (Tr. 2056, 2057). In short the difference between Wilder's measurement of the assumed derivative and the true derivative measured in the plaintiffs' Problem Check arrangement, is the essential difference between an incomplete and a complete check. This is one of the basic defects eliminated by plaintiffs' Problem Check. This distinction coupled with the problem setup disturbance characterizing the Wilder procedure, demonstrates the inapplicability of this prior art technique to the patented invention.

(f) The Mackey/Linz Tempco Vought (LTV) Check

G30. This check and the related exhibit (Dx NC) was described by Benford Mackey of LTV and is virtually identical to the Wilder/Martin check (Tr. 2063).

G31. Neither the Wilder/Martin nor the Mackey/LTV check suggests the measurement of the initial value of the derivative (Tr. 2056). Use of these checks impaired the overall capacity of the computer (by eliminating the summing function of each integrator) in order to overcome some of the deficiencies in the checking art (Tr. 2058-2062). Accordingly, their failure to recognize that a measurement of the initial value of the derivative would eliminate not only these shortcomings but the remaining defects as well, while preserving at the same time the total capacity of the machine (Tr. 2058, 2059), is further evidence of the non-obvious character of the invention.

(g-h) The Favreau/Hughes Check

G32. Romeo R. Favreau, an officer and director of Electronic Associates, Inc., defendant in the related suit brought by plaintiffs against that company for infringement of the McCoy patent in suit, testified from memory alone (Tr. 1408 et seq.) to certain checks allegedly performed by him while employed at Hughes Aircraft in the period 1950 through 1954.

G33. The first check described by Mr. Favreau was practiced on a Reeves REAC computer (Dx JW). It utilized the initial condition circuits as was done in the con-

ventional IC mode and involved a measurement of the voltages appearing at the outputs of various components associated with the integrators (Tr. 1437, 1438).

G34. As an attempt at checking the signals summed within the integrator, all of the patchcords connected thereto would be pulled out and plugged into a separate summing amplifier the output of which was then read (Tr. 1439). It follows that the operator then had to remember to replace all of these patchcords in their proper holes at the integrator input terminals so that the setup would be properly restored prior to the start of computation. Accordingly, this check, like the IC check, did not verify that the patchcords connected to the integrators were in fact in their proper holes nor did it check the associated patch bay contacts, nor the summing networks of the integrators. Each of these elements are check for each integrator by measuring the initial derivative as taught in the plaintiffs' patent (Tr. 251, Px 367). In short the Favreau patchcord pulling check suffered from the basic deficiencies of the prior art IC check and in one sense aggravated these deficiencies by virtue of the patchcord pulling operation.

G35. In his direct testimony Favreau also referred to an additional check practiced on special integrators of the REAC computer which included a switch and associated circuitry not found in the conventional integrators in the same equipment (Dx JW, OH, OI; Tr. 1439-1441, 1515-1528). The function of this switch was to enable operators to convert integrators to summers in those problems where additional summers were required and all of the integrators

were not needed (Tr. 1540, 1541). By throwing this special switch to a "special" position and by connecting a feedback patchcord between the output and input of the unit, it would be converted to a summing amplifier and would be controlled in the operation of the computer in the same way that a summing amplifier was controlled (Tr. 1516, 1526).

G36. Favreau testified during his direct examination that he manipulated this switch and inserted the additional patchcord for checking purposes on those integrators equipped with this optional arrangement (Tr. 1516). If this were done, then a measurement of the summing junction current of that integrator could theoretically be accomplished (Tr. 1440). Favreau admitted however that performing this operation disturbed the problem setup, eliminated the test voltage associated with that integrator, and except in special cases, closed rather than opened the loop around the integrator now functioning as a summer (Tr. 1543-1545).

G37. There was no corroborative evidence or documents supporting Favreau's testimony, the public character thereof, or alternatively, the absence of abandonment, suppression or concealment. In any event, Favreau admitted on cross-examination that he merely "assumed" that this switch had been operated for checking (Tr. 1541-1543). There is no showing of a clear and convincing character that this Special switch was manipulated by Favreau for checking purposes. Moreover, even if the switch had been so operated, the procedure would not suggest McCoy's Problem Check because it required a dis-

turbance of the computer setup, closed the computation loop, and eliminated the test voltage, all contrary to the teachings of the McCoy patent.

(i-j) The Ulrick Naval Ordnance Lab (NOL) Checks

G38. Bruno Ulrick testified on behalf of defendant and described from memory alone two checking procedures he purportedly practiced at the Naval Ordnance Laboratory in 1953 (Tr. 1710 et seq.). These checks were identical to the two procedures described by Favreau. The patch-cord pulling check suffered from the basic deficiencies of the IC check for the reasons already noted in the discussion of the corresponding Favreau check and, hence, is no more pertinent than the art considered by the Patent Office (Tr. 1733).

G39. Ulrick's testimony that he operated the Special switch was uncorroborated by any written documents or other evidence and his demeanor and testimony during cross-examination and when confronted with impeaching evidence (Px 425) raised a reasonable doubt that the switch was so used by him (Tr. 1729-1734). Ulrick's testimony did not supply clear and convincing evidence of this alleged prior art procedure, nor its public character, or alternatively, the absence of suppression, concealment and abandonment.

G40. Apart from the question of proof, and as in the case of Favreau, Ulrick's operation of the Special switch and insertion of the feedback patchcord fails to suggest the Problem Check invention because the procedure re-

quires the closing rather than opening of the integrator loops, eliminates the integrator test voltage, can only function in special areas of the problem setup, and depends on a disturbance of the computer setup, thereby aggravating the human error problem.

(k) Hussey Tests

G41. Joseph Hussey, a former head of defendant Beckman's computer operation and one of the Beckman engineers who responded to Warshawsky's request for help (Tr. 1130), testified on behalf of defendant (Tr. 1060, et seq.; Dx AN, BD, CD, LA, NA-1-NA-6, NR, NT, NS, NU) to certain tests he performed at Northrup Aircraft in the period 1950-1952 (Tr. 1078-1096). All of the procedures described by him involved voltage measurements accomplished by disturbances of the problem setup. These variously took the form of patchcord manipulations, manual test voltage insertions and the manual insertions of feedback resistances (Tr. 1079, 1081, 1082, 1085-1087, 1089, 1090, 1092, 1093, 1095, 1127). There was no evidence of a measurement of the initial value of the derivative nor anything suggesting same (Tr. 1125, 1126). The Hussey procedures, involving as they did substantial disturbances of the computer setup, were pregnant with possibilities of human error (Tr. 1132).

G42. The pertinent phases of Hussey's testimony were based upon memory alone, uncorroborated by any documents or other contemporary evidence (Tr. 1124, 1125). Furthermore, Hussey could not specifically recall the circuits involved in the check he described (Tr. 1139).

Findings of Fact

G43. Defendant's witness Hussey described various checking procedures he purportedly performed at Northrup in 1952 (Tr. 1060, 1061, 1078 et seq.). One was a step-by-step check of each component (Tr. 1078-1096) which required the manipulation of patchcords (Tr. 1082, 1085, 1086, 1089, 1090) and resistors (Tr. 1092, 1093, 1095). Hussey admitted that it would be apt to call it a "patch-cord-pulling resistor-plugging, trouble shooting technique" (Tr. 1172). The operator performing this check was plainly oblivious to the problem of computer disturbance (See also Tr. 1131, 1132). Moreover nothing suggesting a measurement of the initial derivative is found in the procedures he described.

In the course of one component check he described involving the test of a multiplier (Dx NA-4; Tr. 1086) he purportedly checked a "loop" including the inputs of an integrator (Tr. 1095, 1096—this testimony is relied on by defendant as allegedly showing a complete check of an entire loop involving an integrator). However, he admitted on cross-examination that he could not specifically remember whether or not an integrator was involved in this test (Tr. 1139) or what specific problem was wired (ibid) and that it was a check of the multiplier (Tr. 1128). There was no testimony of a check of computing element B, allegedly a part of this loop (Dx NA-4). The Hussey testimony on Northrup procedures does not describe a check which is complete, non-disturbing, or employing a measurement of the initial derivative.

Defendant urges that the patented Problem Check was obvious to a person skilled in the art in view of the

checking procedures performed by Hussey at Northrup but, the evidence points to the contrary conclusion. In 1954, Hussey addressed himself to the computer checking problem in responding to the request from Warshawsky at WADC (Px 19) and, on behalf of Beckman, submitted his computer checking proposals (Px 21) in the hopes of obtaining the WADC contract. Hussey surely did not see any connection between his prior Northrup checking techniques and Problem Check since he failed to suggest anything resembling Problem Check in his proposals to WADC in 1954. Later, in 1956, after having learned of plaintiff's Problem Check and after incorporation of a simplified version in the Beckman 1100 computer (Tr. 406-415), he characterized the Beckman Problem Check as "extremely powerful" and a check which made it possible "for the first time * * * to confirm conveniently and rapidly the correct setup of an analog computer" (Px 34, 45; Tr. 1149-1153). Moreover, before a meeting of the Simulation Council, Hussey agreed that the 1100 version of Problem Check solved a problem "that has probably bothered all of us at one time or another" (Tr. 1148, 1151).

Hussey, as head of Beckman's computer operation and chief engineer, was certainly a man possessed with at least ordinary skill in the art. Problem Check was not obvious to Hussey in 1954 and it follows that the checking techniques practiced by Hussey at Northrup do not suggest the claimed invention.

G43(a). The Beckman 1030 analog computer sold in 1952 included four 6-pole double throw relays whose con-

tacts were available at the patchboard (Tr. 1100, 1101, 1102, Dx NT, LA). On this 1030 computer, the customer would select a terminal to be used as the summing junction for an integrator. This terminal was not connected to a relay contact or ground (Tr. 1108, Dx LA). The 1030 computer utilized Add-A-Plugs which enabled voltages to be measured at the ends of the patchcords hopefully connected to the input resistors of the integrator without disturbing the problem setup (Tr. 1109, 1110, 1122, Dx NV, LA, NA-6). The voltage measurement did not indicate whether in fact the patchcords were so connected (Tr. 1126, 1127).

(l) The Prior Art Thomas Patent

G44. This patent (Dx CG) disclosed an analog computer having provision for utilizing switches instead of patchcords and the like to control the type of computing function performed by the operational amplifiers. Nothing in this patent suggests a measurement of the initial derivative or anything of significance pertaining to the patented Problem Check.

(m) The Hunt Check

G45. Defendant also put in evidence the deposition testimony (Dx NI; Tr. 1739 et seq.) and exhibits of John Hunt employed by the Link Aviation Division of General Precision Corporation. That testimony and the related exhibits describe a checking arrangement designed for use in an aircraft simulator (Tr. 1741). Such simulators are designed for a single purpose, are pre-wired, and have

no patch bay or patchcord system (Tr. 1743). Accordingly, an important part of the problem burdening general purpose computers, namely, the correctness of the patchcord configuration, does not exist in this type of equipment.

G46. Aside from this distinction the Hunt checking arrangement is basically a component test which checks the amplifiers in the simulator one at a time by means of selector switching (Tr. 1787). The Hunt prior art checking arrangement provided an electromagnetic relay at the output of each integrating amplifier for disconnecting the output of the integrator from the remainder of the analog computer (Tr. 1761, Dx DL). This same relay opened the closed-loops of the analog computer (Tr. 1780, 1781, Dx DF). Additional relay contacts connect a feedback or shunt resistor between the input and output terminals of the integrating amplifier, thereby disabling the integrator by converting it to a summing amplifier (Tr. 1759, 1760, 1765, Dx DL). The interconnections between computing elements are not checked (Tr. 1786). Also, the Hunt concept is the opposite of what is taught by McCoy, since instead of measuring the signal appearing at the integrator summing junction, in the Hunt arrangement a test signal is injected into the summing junction and the resultant amplifier output measured (Tr. 1789).

G47. The Hunt check is seen to be incomplete, is not concerned with the human error problem, and would not suggest the measurement of the initial value of the derivative to the man of ordinary skill in the art.

(n) The Cook Check

G48. Charles Cook testified on behalf of defendant (Tr. 1159 et seq.; Dx BG, NY, NV, NZ, OB) that he performed certain checks on the Goodyear GEDA computer at the Motorola facility in California. A similar computer was already in operation at Warshawsky's WADC facility in Dayton, Ohio (Tr. 617). Cook testified during his direct examination that he practiced these on the Goodyear computer in the course of solving a problem known as the "Homing Sky Mine" which involved an air-to-air missile.

G49. Cook first became acquainted with the Goodyear GEDA computer in the "summer of 1954" (Tr. 1185), this GEDA computer having been delivered to the Motorola facility in July, 1954 (Stipulation). The employment records at Motorola show that Cook's employment there commenced July 6, 1954 (Stipulation). However, Cook testified,

> "I couldn't go with them (Motorola) immediately because I had to finish writing reports for a simulation which was still going on when I left. So from about June of 1954 (actual date July 6, 1954, established by stipulation) on for another year, I was going back and forth between the two plants" (Tr. 1161).

The Corona payroll records were produced under subpoena and revealed that Cook was carried on the records as a full time employee at Corona until September 12, 1954 and was, thereafter, carried on a WAE status (payment when actually employed) until September 23, 1955 (Tr. 1917 to 1919).

Findings of Fact

The only evidence in the record through which defendant seeks to establish when Cook's checking procedure was first used is the uncorroborated testimony of Cook as follows:

> "I can't remember exactly when I first used it, because that was several years ago, about 14, something like that, but I am quite sure that it didn't take us more than the time it takes to set it up to think that this would be a good way to do it. I would be, as I said, morally certain that we used it on this (Homing Sky Mine) problem" (Tr. 1187).

The report on the Homing Sky Mine (Dx NY) is dated "November 1954".

In view of the Corona payroll records, the date of the Homing exhibit, and the uncertainty of Cook's testimony, the Court is not convinced that Cook started using his checking procedure at Motoroia prior to September, 1954, when his fulltime employment status at Corona terminated. By this time the McCoy invention had been conceived, described and disclosed (Findings E11-E13).

G50. Mr. Cook, testifying from memory alone, described and demonstrated his checking procedures to the Court. These procedures involved the removal of patchcords in the integrator circuits, establishing test voltages by the manipulation of initial condition potentiometers (Tr. 1180, 1183-1185, 1189, 1190) and the measurement of the summing junction current in certain integrator circuits with a special summing amplifier (Tr. 1183, 1184). In this

respect the Cook procedure differed from the measurement techniques employed in the IC check and variations thereof and could have provided a measurement of the initial derivative.

G51. However, the measurement depended upon a "major disturbance" (Tr. 2065) of the computer setup; initial condition settings had to be disturbed and patchcords removed (Tr. 1180, 1183-1185, 1189, 1190). The operator would have to remember to restore all of these connections and adjustments prior to the start of computation (Tr. 2065, 2066). Cook admitted that with the patchboard wired up "It would be very difficult to tell whether all the wires were indeed present" (Tr. 1179) and also stated that "It is very easy to leave wires out and to put in wrong resistors" (Tr. 1180). In effect, Cook admitted that these disturbances aggravated the human error problem.

G52. Cook's procedure did not evidence any recognition of the concept of a non-disturbing measurement of the initial value of the derivative (Tr. 2066). Also, the Cook procedure failed to provide a complete check since, as admitted by Cook on cross-examination, his procedure could not be used on all integrators, namely those that did not have automatic IC switching conditions (Tr. 1242-1244) and could not determine whether certain patchcords were operative, these being the patchcords between the summing junctions and the IC relay terminals (Tr. 1237).

G53. There was no corroborative documentary evidence describing the procedure purportedly practiced by Cook. The document (Dx NY) showing the computer setup in the

Homing Sky Mine problem is dated November 1954, which is after McCoy conceived, disclosed and commenced reduction to practice of the patented invention. Moreover, the document, far from corroborating Cook, contradicts his testimony. He testified during cross-examination that in practicing the test it was customary to apply initial conditions to all integrators and that these would be indicated on the diagram (Tr. 1227). The diagram (Fig. 17 of Dx NY) on the other hand does not show initial conditions for every integrator. In the case of integrator number 21 there is no indication whatever of the application of an initial condition voltage (Tr. 2070). In contrast, a much later Cook exhibit, dated April 24, 1959 and May 12, 1959 (Dx OB), describes another computer problem and does not include indications of the application of initial conditions to all integrators (Tr. 2070, 2071).

G54. On the basis of the testimony and documents adduced, it cannot be said that defendant proved, by the preponderance of the evidence, let alone by clear and convincing proof, that Cook performed the procedure he described before the invention of Problem Check by McCoy. The earliest document, Dx OB, which is consistent with Cook's testimony, is dated May 12, 1959, long after McCoy's invention. The proof is similarly deficient as to the public character of the Cook procedure prior to the invention of Problem Check by McCoy, or the use of the Cook procedure without suppression, concealment or abandonment.

G55. Aside from the inconsistencies and omissions, the credibility of the Cook testimony is questionable because

McCoy had disclosed his invention and it had been disseminated at about the time that Cook claimed to have made the check. Problem Check was disclosed in August 1954 and starting in the summer or September of 1954, Loveman of Reeves traveled around the country visiting installations, including some near Cook's facility, during which visits he talked to people about the features of the REAC 400 computer including the Problem Check feature (Tr. 2121-2123). There is accordingly the possibility that if Cook did practice his check in 1954, it was after hearing about Problem Check.

(o) The Sanders Check

G56. James W. Sanders, until recently an EAI employee, testified on behalf of defendant that he practiced a certain test procedure on equipment manufactured by Electronic Associates, Inc. during the debugging thereof in the early part of 1954 while at the Convair facility in Fort Worth, Texas (Tr. 1256 et seq., Dx EH, FS, FV, GB, GC, MY, OE, OF).

G57. The Sanders' procedure is of the same general character as the Cook procedure involving in this case the manipulation of bottle plugs rather than patchcords. These bottle plugs are the same in principle as patchcords, except that they have a rigid rather than a flexible construction (Tr. 1272; Dx MY).

G58. The Sanders' procedure fails to render the patented Problem Check obvious for the reasons noted in

connection with the Cook procedure (Tr. 2064, 2065). Significantly, in later EAI computers the instrumentalities with which Sanders allegedly practiced his check exist side-by-side with EAI's version of Problem Check (Tr. 1379).

G59. As in the case of Cook, the testimony of Sanders is without any other supporting evidence (Tr. 1315). He relied upon certain documents (Dx EH) dated in September 1955 and April 1956, i.e., after McCoy's Problem Check, as being "like" documents describing the machine on which he purportedly practiced the procedure. He admitted on cross-examination, however, that the documents in evidence were not in fact the same as those describing his machine and also agreed that there were differences between the descriptions found in the exhibits and the actual structure of the machine on which he purportedly practiced the check (Tr. 1314-1317). Moreover, the check required the use of a special two-prong plug which was not described anywhere in the manuals he claimed described the machine (Tr. 1313).

G60. There are also inconsistencies between the procedure orally described by Sanders and the circuit configurations he claimed existed as a consequence of that procedure. Exhibit EH, Figs. 3-IV-2 and -3, which purports to illustrate the integrator circuit of the machine on which Sanders practiced the check shows a relay K1 the condition of which determines whether or not the summing junction measurement described by Sanders can in fact be made (Dx EH, pp. 4-I-1, 2). Exhibits OE and OF on the other hand, which are circuit diagrams prepared by Sanders to show the circuit configuration which supposedly existed during his

check, fail to disclose any relay K1. Accordingly, the check described by Sanders and purportedly shown by Exhibits OE and OF omit a description of a circuit component which determines whether or not the measurement could have been made.

G61. Apart from the inherent dangers in accepting alleged prior uses, there are other circumstances warranting a high standard of proof in the case of Sanders. He claimed to have practiced his debugging procedures in the "first three to four months" of 1954 (Tr. 1285) and stated that EAI personnel visited his facility at that time and modified the machine (Tr. 1321). Jerome Kennedy of EAI "was in and out quite a bit at that time" (*id*) and the EAI people "may have seen" the Sanders' procedure (*id*). EAI's immediate recognition and appropriation of the Problem Check technique after disclosure thereof by McCoy is in marked contrast with the failure of Sanders' alleged test to generate even a ripple of interest among these same EAI people visiting his facility and obviously concerned with how their machine was behaving.

G62. Furthermore, Sanders wrote the specification for a subsequent EAI machine (16-31R, project 3312) delivered to Sanders' facility (Tr. 1266, 1268; Dx GB). This second computer was ordered in May of 1955 and Massell of EAI was specified as the Project Engineer (Dx FF). It called for EAI's first version of Problem Check (Dx GB; Tr. 1266-1268). If Sanders had practiced the derivative measurement procedure as claimed by him, it is likely that he would be credited as the originator of the Problem Check

system in the second EAI machine. But Massell testified that he and Favreau conceived this arrangement after learning of Reeves' Problem Check (Tr. 1368, 1369, 1380).

G63. These later circumstances do not conform with the alleged 1954 activities of Sanders and raise further doubts justifying a critical evaluation of defendant's evidence on this subject. The alleged prior art procedure of Sanders is not proven by clear and convincing evidence.

G64. As in the case of Cook, it must be remembered that the time when Sanders allegedly performed his check is very close to McCoy's conception and public disclosure date, raising the possibility of derivation from McCoy. This is not a case where an alleged prior use occurred many years before the making of a patented invention, and the only question relates to the nature of the use as distinguished from the time it was performed. In the case of Cook and Sanders, however, a handful of months makes the difference between viable prior art and derivation. A reasonable doubt is inherent in unsupported recollections in fixing an event within so short a span of time after a lapse of fourteen years.

H.

Patentability of the Invention

H1. The state of the art forming the background of the patented invention is manifestly void of any arrangement or procedure which suggests the key distinctions of the claimed invention, namely a combination of circuit elements yielding a complete and error-free static check.

Findings of Fact

H2. None of the alleged prior art items individually suggest the claimed arrangement of a non-disturbing measurement of the integrator initial derivatives, and the differences between each item of prior art and the subject matter defined in the claims in suit would not have been obvious at the time the invention was made to a person having ordinary skill in the art.

H3. This evaluation is not changed by considering the prior art taken together. There has been no evidence showing any logical combination of the prior art references which would suggest the claimed subject matter and any rational combinations which can be hypothesized lead to aggravations of the disturbance problem and a concomitant magnification of the human error defect.

H4. These findings are reinforced by the so-called secondary considerations, all of which suggest that McCoy's solution was not obvious.

H5. The problem of checking was of overriding importance; the very utility of the computer depended upon a valid solution and a valid solution was always in doubt where the check was incomplete or involved disturbances.

H6. Workers skilled in the art had an obviously deep and abiding concern with the problem of checking. This theme dominates the record and is fairly summarized in one of the Simulation Council letters (Px 170, March 1953):

> "What Makes You Think Your Solution Is Correct?" "Breaths there a simulation man who hasn't

been bothered by this? If not put by others, the question will probably arise from his own sense of integrity."

H7. The need for better checking was widely recognized. This stands out in Warshawsky's story, and in the intense work at MIT. It was also expressed in other literature as well:

> "The errors involved in programming, patching and dial setting are those of the operator and adequate checking procedures must be taken to minimize them." (Px 230; Tr. 2082).
>
> • • •
>
> "A more fool-proof interconnecting and gain setting system is vitally needed, as is a method for storing problems. An automatic system for testing components and locating faults rapidly is necessary" (Px 436, page 27)

H8. In response to this need many "diverse" proposals were made and techniques tried (Tr. 2082-2093). It was Dr. Jackson's experience, corroborated by the literature, that:

> "There were many different approaches that were being tried, or many suggestions being made, but very little agreement as to what the best approach would be" (Tr. 2083).

Most of these approaches have been referred to in the findings on the state-of-the-art. Many, like Burnside's patchcord elimination scheme (Px 230; Tr. 2081) and the proposals of RCA and the Bureau of Standards (Px 436) were outright failures (Tr. 2093), while others, like MIT's

one-of-a-kind duplicate patchbay, failed to progress beyond a single use.

H9. Men of more than ordinary skill in the art grappled with the problem and failed to see what McCoy saw. The Rand engineers couldn't get beyond the IC check. The best Favreau could do was to pull patchcords. Warshawsky and his colleagues, who were "obsessed" with checking, (Tr. 654), failed to recognize the solution and wondered, after McCoy, why "we didn't think of this ourselves" (Tr. 647). Except for McCoy, the engineering talent of the companies enlisted by Warshawsky never thought of it either.

H10. There is a considerable likelihood that the essence of all the alleged prior art now brought forward by defendant was known to the engineers who sought to provide a better checking system for Warshawsky at WADC in 1954. The IC check was widely practiced and well known to these people. All of the other alleged prior art was shown to be essentially the same, or less effective, than the IC check, and/or was practiced on computers manufactured by the companies competing at WADC. Even with the pertinent prior art at their finger tips, the concept underlying Problem Check eluded the engineering talent of the analog computer industry at a time when their attention was focused on the need for developing a better checking system. The patented Problem Check was not obvious to them.

H11. Only McCoy came forward and created a checking system which enabled the operator to make a complete

static check of the computer and a complete check of the jungle of confusion at the patchbay by requiring no more than modest structural changes which succeeded in eliminating both of the major defects burdening the prior art. This is an unusual and surprising consequence further evidencing the unobvious character of his invention. Further evidence thereof is apparent in his decision to monitor the sensitive and delicate summing junction area (Tr. 319, 358-361) theretofore avoided in the art (Tr. 1693). This innovation is consistent with the inventor's general accomplishments and reputation. He designed the first Reeves computer (Tr. 2005) and was elected a Fellow of the IRE, "quite an honor" in the opinion of Dr. Jackson (Tr. 267), for "contributions in the field of servo control systems and analog computers" (Px 401).

H12. The industry's reaction to Problem Check confirms this finding of patentable innovation. Warshawsky was plainly impressed. Dr. Jackson called it a "breakthrough" (Tr. 278). It was quickly appropriated by Beckman and EAI. All large EAI computers embody Problem Check as do the bulk of Reeves 400 computers. Ninety percent of the defendant's 2100 computers and all 2200 systems have it.

H13. Dr. Korn stated that "most analog computers have this in one way or another nowadays" (Tr. 1604) and Dr. Jackson indicated it "would be very uncommon to find a large computer that has been manufactured recently, at least, that did not have some type of problem check" (Tr. 379). Its utility has actually increased over the years (Tr. 706).

Findings of Fact

H14. This record of performance substantiates the patentable nature of plaintiff's invention. Dr. Jackson testified that McCoy's invention promoted the progress of the science and art of static checking when it was adopted, is doing so today, and would have "definitely" done so in the period 1949 to 1954 (Tr. 2094).

I.

Late Claiming Defense

I1. An analysis of the prosecution history of the patent (Dx CF) in suit establishes that the checking arrangement which is the subject matter of claims 7, 8 and 13 in suit was disclosed and claimed in the original application as filed and continued to be claimed during the entire pendency of the application.

I2. The specification and drawings for the patent in suit were filed as part of the original application in the United States Patent Office on April 20, 1955. Between the time of original filing and the grant of the patent, no new matter was added to the original disclosures. Although there were a few minor editorial revisions thereof, the specification remained essentially unchanged. The minor changes to the drawings, made at the direction and with the consent of the Patent Office Examiner, merely illustrated conventional ground connections already implicit in the original specification.

I3. Claim 2 of the patent reads as follows:

"2. In an apparatus for checking the operation of an electronic analog computer which includes an in-

tegrator having an amplifier and a feedback condenser connected across the amplifier, said integrator having an input and an output connected in the computer circuit, the combination which comprises means for disconnecting the output of the integrator from the computer circuit and substituting a constant voltage of a predetermined value in the computer circuit in place thereof, means including a resistor for cancelling the effect of the feedback condenser in the integrator, and means for measuring the output of the integrator when the effect of the condenser is cancelled."

Patent claim 2 describes the illustrative embodiment of the McCoy static check invention shown in the drawings and described in the specification. All of the language of claim 2 of the patent is found in original claim 2 of the application as filed. Certain language appearing in original claim 2 of the application which related to the dynamic check of the application was cancelled therefrom, but insofar as the language of original claim 2 related to the static check apparatus, it appears unchanged in the patented claim.

I4. Patent claim 2 covers apparatus for checking the operation of an electronic analog computer which checking apparatus is the equivalent of the accused Derivative Check of defendant's 2100 and 2200 computers. The apparatus defined in claim 2 and the Derivative Check apparatus of defendant include (1) means for developing the special test voltages (Problem Check voltage) (Tr. 1800-1802) and (2) means for measuring the initial value of the derivative (Tr. 1847, 1850). Therefore the apparatus defined by claim 2 and that found in the accused computers represent one and the same invention (Tr. 1799, 1800).

Findings of Fact

I5. In claim 2 of the patent the clause "means for disconnecting the output of the integrator from the computer circuit and substituting a constant voltage of a predetermined value in the computer circuit in place thereof" describes the corresponding apparatus disclosed in the patent in suit (Tr. 224). In the accused system also, a constant voltage of predetermined value is substituted in the computer circuit in place of the normal output of the integrator by means of the false IC circuitry (Tr. 1801, 1802). Accordingly, in the 2100 Beckman computer there is connected a constant voltage in place of what would normally be the output of the integrator and, hence, this arrangement is covered by the quoted language of claim 2 (Tr. 1806).

I6. The terminal clause of patent claim 2 specifies "means for measuring the output of the integrator when the effect of the condenser is cancelled." This clause, when construed in accordance with the provisions of 35 U.S.C. 112, covers the corresponding structure described in the specification and equivalents thereof. The specification of the patent describes that when the conditions set forth in the preceding portion of the claim are established "the outputs of the integrators will be proportional to the initial value of the derivatives applied thereto" (Column 4, lines 69, 70). Consequently, in the McCoy patent the measurement of the output of the disabled integrator (the integrator condition when "the effect of the condenser is cancelled") is in fact a measurement of the initial derivative applied to the integrator. This is precisely what Beckman's Derivative Check system is designed to measure.

The quoted language accordingly describes the full equivalent of the measurement achieved by the accused system.

I7. Claim 2 of the application was held allowable in the first Patent Office action of March 30, 1956 and remained allowed throughout the prosecution of the application.

I8. Claims 7 and 8 of the patent were introduced by amendment dated October 1, 1956, being therein numbered claims 15 and 16, respectively. Except for minor editorial corrections those two claims were held allowable as filed.

I9. The Patent Office Examiner recognized and held that the claimed means for measuring the voltage appearing at the input of the integrating circuit, as specified, for example, in patent claim 7 (application claim 15), was the same thing as the means specified in claim 2 "for measuring the output of the integrator when the effect of the condenser is cancelled." This appears most clearly in connection with the Examiner's ruling regarding method claims 20 and 21, which were introduced into the application by the same amendment of October 1, 1956. Both those method claims specified the step of "measuring the voltage appearing across the *input* of the integrator." (emphasis supplied) In acting on claims 20 and 21, the Examiner ruled "These claims cover the same territory as that covered by allowed claims 1-6 * * *" (Dx CF, page 35). By this ruling the Examiner recognized and held that allowed claim 2, which called for measuring the output of the disabled integrator, covered the same territory as claims which called for measuring the input to the integrator.

Findings of Fact

I10. Claims 7 and 8 of the patent introduced no new matter but merely made express what would have been regarded as the equivalent of the subject matter set forth in original claim 2 of the application as filed. Claims 7 and 8 cover the same territory as that covered by claims 1-6 which appeared in the original application as filed.

I11. In the Patent Office action of April 20, 1959 patent claims 7 and 8 (application claims 15 and 16) were allowed and in the same action the Examiner again ruled that claims 20 and 21 reciting measurements at the input are the equivalents of the disclosed apparatus:

> "Claims 20 and 21 are rejected as being improper method claims. The recited steps are drawn to the operation of the apparatus disclosed *or its equivalents*. The method asserted has no existence independently of the disclosed apparatus or its equivalents and as such is not patentable." (Dx CF, page 45, original emphasis).

I12. Patent claims 7 and 8 are directed to the same invention as that initially set forth in original claim 2 of the application and are consonant with the objects and disclosures of the invention set forth in the original application as filed.

I13. There is no evidence that the claims introduced by amendment of October 1, 1956 were drawn for the purpose of covering the checking system of the EAI computer or that they were drawn to cover any particular computing apparatus.

I14. Claim 13 of the patent was first introduced into the application by the amendment of October 14, 1959 as claim 26 therein (Dx CF, page 47). Patent claim 13 is likewise directed to the same invention as patent claims 7 and 8 and it introduced no new matter into the application. Patent claim 13 is more specific than claims 7 and 8 in that it articulates limitations to a series input resistor of the integrating circuit and further specifies that the measuring means include amplifier means coupled to such resistor for measuring the response of the remaining elements of the computer. These more specific limitations are shown and described in the original drawings and specification as filed and are merely rendered explicit in claim 13.

I15. Patent claims 7, 8 and 13 were presented to the Patent Office for the purpose of particularly pointing out and distinctly describing the subject matter of the invention as disclosed in the patent application as filed. The Patent Office never raised any question concerning the support of claims 7, 8 and 13 by the description in the application as originally filed.

I16. "In the Spring of 1955 EAI received an order from Convair of Fort Worth, Texas, to build a new general purpose analog computer (Stipulation at Tr. 2113, 2114) and prior to October 1, 1955 offered for sale in a contract of sale entered into between EAI and Convair, a static checking system substantially the same as was subsequently delivered in the computer (Pre Trial Order Admitted Fact 74). No computer was on hand to fill the order when the contract was made (Stipulation ibid). The ordered com-

puter was laid out and manufactured during the year 1955 and was not completed, operated or delivered until November, 1955. Changes were likely to have been made in it during the course of manufacture. When completed and delivered, it had a static checking system similar to that of defendant's 2100 except that the system was incomplete in that it had no provision for introducing a "false IC" as the source of known checking voltage (Stipulation at Tr. 2113, 2114). Consequently, even as delivered in December, 1955, this EAI computer did not contain all of the elements set forth in Claims 7, 8 and 13 of the patent in suit (Tr. 524, 529, 570-572, 599). There is no evidence that any information regarding the EAI contract was ever made available to anyone outside EAI and Convair at any time prior to October, 1955."

I17. EAI's proposal to WADC (Px 24) is similarly deficient in failing to disclose the "False IC" arrangement. There is no evidence that the EAI proposal was ever made available to anyone outside EAI other than Mr. Warshawsky.

I18. During the latter half of 1955 EAI issued a bulletin entitled "Preliminary Information Release" which contained a circuit drawing showing its derivative checking system. That drawing also failed to disclose the false IC source of known voltage. This bulletin was identified as "PIR No. 2" and is undated. Another bulletin identified as "PIR No. 15" was shown to have been published on or about July 7, 1955. PIR No. 2 (Dx EC) has not been proved to have been published before October 1, 1955.

Findings of Fact

I19. An advertisement of EAI (Dx EJ) appearing in June 1955 mentions the words "problem checks," but fails to include any descriptive material or any real indication of the contemplated arrangement.

I20. Defendant has not proved that any checking systems corresponding to that of the 2100 and 2200 Beckman computers or any equivalent EAI system was in the public domain on or before October 1, 1955.

J.

Other Defenses

J1. There is no sufficient evidence in the record which would support a finding for defendant on alleged Affirmative Defenses not previously discussed, namely the Affirmative Defenses alleging patent invalidity or unenforceability because (1) of file wrapper estoppel (Affirmative Defense D in the complaint), (2) the claims do not define statutory subject matter (Affirmative Defense E), (3) a supplemental oath was required (Affirmative Defense G), (4) the claims recite single functional means (Affirmative Defense I), (5) the claims recite function at the point of novelty (Affirmative Defense J), (6) plaintiff misrepresented the prior art to the Patent Office (Affirmative Defense K), (7) unclean hands or unfair competition on the part of plaintiff (Affirmative Defense L) or (8) restraint of competition by plaintiff and patent misuse (Affirmative Defenses M and N). All other alleged defenses have been dealt with specifically in preceding sections of these findings.

Conclusions of Law

1. This Court has jurisdiction of the parties and of the subject matter of this action and venue is properly laid under 28 U.S.C. 1400(b).

2. The plaintiff, Dynamics Corporation of America, by assignment from its former subsidiary, Reeves Instrument Corporation, now a division, is the owner of the entire right, title and interest in and to the patent in suit and is the owner of all rights to recover damages for the infringement of said patent.

3. United States Patent No. 2,967,997 is valid as to all the claims in suit, namely claims 7, 8 and 13.

4. The patent in suit was regularly issued and is presumed valid. Defendant has failed to overcome this presumption by convincing evidence of error. One who is otherwise an infringer, who assails the validity of a patent, fair upon its face, bears a heavy burden of persuasion and fails unless his evidence has more than a dubious preponderance; 35 *U.S.C.* §282; *Radio Corp. of Ameria* v. *Radio Engineering Lab., Inc.,* 293 U.S. 1, 7-8 (1934); *Bianchi* v. *Barili,* 168 F.2d 793, 795 (9th Cir. 1948); *Moon* v. *Cabot Shops, Inc.,* 270 F.2d 539, 541 (9th Cir. 1959); *Adams* v. *U.S.,* 383 U.S. 39; 86 S.Ct. 708 (1966).

5. Defendant has infringed said United States Patent No. 2,967,997 by making, using and selling its 2100 and 2200 Series General Purpose Electronic Analog Computers containing the Derivative Check system (35 U.S.C.

271(a)). Defendant has further infringed said patent by instructing, advising and actively inducing its customers to use Derivative Check in said Series 2100 and 2200 General Purpose Electronic Analog Computers (35 U.S.C. 271(b)).

6. Claims 7, 8 and 13 of the patent in suit clearly describe the Derivative Check system of defendant's 2100 and 2200 Series Computers. Since the accused matter falls clearly within the claims, infringement is made out and that is the end of it. *Graver* v. *Linde,* 339 U.S. 605, 607; 70 S.Ct. 854, 855; 94 L.Ed. 1097 (1950); *Stearns* v. *Tinker & Rasor,* 252 F.2d 589, 599 (9th Cir. 1957).

7. Defendant's Derivative Check system is the equivalent of the system described in the illustrative circuit of the patent and performs substantially the same function in substantially the same way to achieve the same result. The claims are clearly infringed. *Graver* v. *Linde,* supra; *Stearns* v. *Tinker & Rasor,* supra; *Hansen* v. *Colliver,* 282 F.2d 66, 69 (9th Cir. 1960); *Solex Laboratories, Inc.* v. *Graham,* 165 F. Supp. 428 (SD Calif., 1958); *Filtex Corp.* v. *Amen Atiyeh,* 216 F.2d 443 (9th Cir. 1954).

8. Defendant has deliberately appropriated the substance of plaintiffs' invention and may not escape liability by the immaterial changes it introduced in the patented combination, *Bianchi* v. *Barili,* 168 F. 2d 793, 800-802 (9th Cir. 1948); *Filtex Corp.* v. *Amen Atiyeh,* 216 F. 2d 443, 446 (9th Cir. 1954); *Coleman Co.* v. *Holly Mfg. Co.,* 269 F. 2d 660, 665 (9th Cir. 1959), nor does the defendant escape

liability on the grounds that the accused checking system incorporates improvements and added features over that of the patentees' claimed invention. *Hansen* v. *Colliver,* 282 F. 2d 66, 69 (9th Cir. 1960); *Neff Instrument Corp.* v. *Cohu Electronics, Inc.,* 298 F. 2d 82, 89 (9th Cir. 1961).

9. The claims in suit particularly point out and distinctly claim the invention in conformity with the requirements of 35 U.S.C. 112.

10. The claims in suit include "means" clauses and have been construed in the light of the specification and in conformity with the provisions of 35 U.S.C. 112. *Adams* v. *U.S.,* 383 U.S. 39, 86 S.Ct. 708 (1966); *Del Francia* v. *St. Anthony,* 278 F. 2d 745 (9th Cir. 1960); *Stearns* v. *Tinker & Rasor,* 252 F. 2d 589 (9th Cir. 1957).

11. The combinations set forth in claims 7, 8 and 13 of the patent in suit set forth new and useful combinations in analog computers within the scope and meaning of 35 U.S.C. 101.

12. No prior art asserted by defendant identically discloses or describes the invention of claims 7, 8 and 13 in suit as set forth in 35 U.S.C. 102.

13. The differences between the subject matter set forth in claims 7, 8 and 13 in suit and the asserted prior art are such that the subject matter as a whole would not have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. 35 U.S.C. 103. *Graham* v. *Deere,* 383 U.S. 1,

83 S.Ct. 684 (1966); *Adams* v. *U.S.*, 383 U.S. 39, 86 S.Ct. 708 (1966).

14. Since experts of extraordinary skill failed to solve the problem which was solved by the invention of the patent in suit although said problem had confronted such persons for a number of years prior to McCoy's invention, the solution of such problem would not have been obvious at the time the invention was made to a person having ordinary skill in that art. *Adams* v. *U.S.*, 383 U.S. 39, 86 S.Ct. 708 (1966).

15. That several of the same experts subsequently recognized and acknowledged the significance of the patented invention, is a further factor in support of the unobvious nature of the patented invention. *Adams* v. *U.S.*, 383 U.S. 39 (1966).

16. Although they are not a substitute for patentable invention, the facts that the invention of the patent in suit achieved commercial success, was copied by defendant, became the standard of the analog computer industry and in doing so satisfied a long felt and previously unsolved need, are considerations tending to demonstrate that the invention would not have been obvious to a person of ordinary skill at the time the invention was made. *Graham* v. *Deere*, 383 U.S. 1; *Adams* v. *U.S.*, 383 U.S. 39; *Hensley Equipment Co.* v. *Esco Corp.*, 375 F. 2d 432 (9th Cir. 1967); *Stearns* v. *Tinker & Rasor*, 220 F. 2d 49, 58 (9th Cir. 1955); *Coleman* v. *Holly Mfg. Co.*, 233 F. 2d 71, 80 (9th Cir.), cert. denied 352 U.S. 952 (1956); *Neff Instrument Corp.* v. *Cohu Elec-*

tronics, Inc., 298 F. 2d 82, 87 (9th Cir. 1961); *Hayes Spray Gun Company* v. *E.C. Brown Company*, 291 F. 2d 319, 322 (9th Cir. 1961); *Stevenson* v. *Lamson Corp.*, 210 F. Supp. 917, 918 (N.D. Calif. 1962); *Troy Company* v. *Products Research Co.*, 339 F.2d 364 (9th Cir. 1964).

17. The new and unexpected results achieved by McCoy in eliminating with modest structural changes the two major defects characterizing the asserted prior art, indicate that the invention would not have been obvious within the meaning of 35 U.S.C. 103. *Graham* v. *Deere*, 383 U.S. 1, 17-18; *Adams* v. *U.S.*, 383 U.S. 39.

18. Since the claimed invention is carried out by the application of instrumentalities proceeding contrary to accepted principles, it would not have been obvious to a person having ordinary skill in the art. *Adams* v. *U.S.*, 383 U.S. 39.

19. The differences between the patented check and the asserted prior art, being in substance the difference between speculative static correctness and verified static correctness, are crucial in the analog computer art and are therefore substantial differences suggesting the non-obvious character of the invention. In the law of patents it is the last step that wins. *The Barbed Wire Patent*, 143 U.S. 273.

20. The fact that each of the physical elements of the McCoy Problem Check Circuit was known does not render the combination of them as set forth in the claims in suit

obvious to a person of ordinary skill, *Adams* v. *U.S.*, 383 U.S. 39, and the patentability of the claimed invention is satisfied even under the strict standards applied in *Great Atlantic and Pacific Tea Company* v. *Supermarket,* 340 U.S. 147, 152 (1950). The failure of the prior art workers to avail themselves of these readily available elements is further evidence of invention. *Adams* v. *U.S.*, supra.

21. The fact that the patented check circuit achieves its results with simple and relatively inexpensive instrumentalities does not render the invention unpatentable. *Goodyear Tire and Rubber* v. *Ray-O-Vac,* 321 U.S. 275; 64 S.Ct. 593; *Neff Instrument* v. *Cohu,* 298 F. 2d 82, 87 (9th Cir. 1961); *Filtex* v. *Amen Atiyeh,* 216 F. 2d 443, 446 (9th Cir. 1954); *Patterson-Ballagh Corp.* v. *Moss,* 201 F. 2d 403 (9th Cir. 1953); *Northrup Architectural Systems* v. *Texas Aluminum,* 153 U.S.P.Q. 837 (C.D. Calif. 1967). Moreover, the fact that McCoy's solution, which eluded the grasp of those skilled in the art, was a simple one, is a factor evidencing the unobvious character of the invention. *American Safety Table Company* v. *Schreiber,* 269 F. 2d 255, 263 (2nd Cir. 1959); *Carnegie Steel* v. *Cambria,* 185 U.S. 403, 446, cited with approval in *National Sponge Cushion* v. *Rubber Co.,* 286 F. 2d 731, 735 (9th Cir. 1961).

22. The claimed invention was made in or about August 1954, being conceived and disclosed at that time, was diligently developed thereafter, was actually reduced to practice by March 1955 and constructively reduced to practice on April 20, 1955. 35 U.S.C. 102(g); 1. *Walker on Patent* 2nd Edition, pages 344, 345.

Conclusions of Law

23. The evidence adduced concerning the checks of Sanders, Cook, Favreau, Hussey and Ulrick do not support defenses of prior uses, prior public knowledge or prior inventions under 35 U.S.C. 102(a), (b) or (g) and do not meet the legal standard of proof required in such cases. *The Barbed Wire Patent,* 143 U.S. 273; *Stearns* v. *Tinker and Rasor,* 220 F. 2d 49; *Cold Metal Products Company* v. *E.W. Bliss Company,* 285 F. 2d 244 (6th Cir. 1960); *Hansen* v. *Colliver,* 171 F. Supp. 803, 809 (N.D. Calif., 1959); modified 282 F. 2d 66.

24. Since the prior art IC check was described in the application for the patent in suit and considered by the Patent Office Examiner in connection with the granting of the claims in suit, the presumption of validity arising from 35 U.S.C. 282 is strengthened with respect to such prior art and its variants. *Natural Sponge Cushion* v. *Rubber Corp. of California,* 286 F. 2d 731 (9th Cir. 1961).

25. The subject matter of claims 7, 8 and 13 of the patent in suit are directed to the same invention originally disclosed, set forth in the objects of the invention, and claimed in the application for the patent in suit as filed, and go no further than to make express what would have been regarded as the equivalent of the specific subject matter originally claimed. No new matter was added to the drawings or specification at any time after the patent application was filed and none of the allegedly intervening activities give rise to intervening rights or statutory bars. The doctrine of Late Claiming is accordingly inapplicable as is the requirement for a supplemental oath. *Engineer-*

ing Development Laboratories v. *RCA*, 153 F. 2d 523, 526, 527 (2d Cir. 1946); *Locklin* v. *Switzer Bros.*, 299 F. 2d 160, 167 (9th Cir. 1961); *Purche* v. *Atlas*, 300 F. 2d 467, 476-477 (9th Cir. 1961); *Linde* v. *Graver*, 339 U.S. 607; *Amerio Contact Plate* v. *Belt-Ice Corp.*, 316 F. 2d 459, 463-464 (9th Cir. 1963).

Dated this 26th day of Nov., 1968.

HARRY PREGERSON

United States District Court Judge

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By

Excerpts from Petitioner's Brief for Appellant

No. 24060

IN THE

UNITED STATES COURT OF APPEALS

FOR THE NINTH CIRCUIT

BECKMAN INSTRUMENTS INCORPORATED,
Appellant,

vs.

REEVES INSTRUMENT CORPORATION and
DYNAMICS CORPORATION OF AMERICA,
Appellees.

BRIEF FOR APPELLANT

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* * *

III.

ARGUMENT.

(a) Introduction.

The contentions of defendant Beckman are as follows:

(1) Claims 7, 8, and 13 of the McCoy patent in suit each is directed to a combination of old and well-known elements which operate in the same way in the claimed combination as each did separately in the prior art, there are no unexpected or surprising results from such combinations, and, as a matter of law, such claims are invalid for lack of invention under the doctrine of *Gt. Atl. & Pac. Tea Co., infra* without regard to the prior art of record.

(2) The McCoy claims are invalid for anticipation by [35 U.S.C. §102] or lack of invention over [35 U.S.C. §103] the prior art of record.

(3) If the McCoy claims are interpreted narrowly enough to avoid such invalidity, none are infringed by the Beckman 2100 or 2200 computers.

(b) The McCoy Patent Is Invalid Under Great A. & P. Tea Co. Case.

* * *

(c) The McCoy Patent Is Invalid in View of the Prior Art I.C. Check.

* * *

(d) McCoy '997 Is Invalid in View of the Martin Company Static Check.

* * *

(e) McCoy '997 Is Invalid in View of the M.I.T. Prior Art Check and Jatras Thesis.

* * *

IV.

CONCLUSION

It is submitted that the District Court failed here to apply properly, or at all, the strict standards for patentability required of p tents for combinations of old elements by the law, and that claims 7, 8, and 13 of the McCoy '997 patent are clearly invalid for anticipation [35 U.S.C. §102], or lack of invention over the prior art [35 U.S.C. §103], or both. Stripped of the aura of esoteric technology with which the alleged invention in suit has been surrounded in the record, we suggest that the statement of Judge Learned Hand in *Foxboro Co.* v. *Taylor Instrument Companies,* 157 F.2d 226 (CCA 2d, 1946), at page 234, is apposite to the facts of this case, as follows:

> ". . . We are to dispose of the question of invention, so far as we can divine, as we think the Supreme Court would dispose of it; and, once the cloud of complicated scientific theory, with which it has been surrounded, is blown away, and the issues are bared as they really are, we have no doubt that that court would hold the claims invalid."

It is further submitted that the District Court erroneously failed to limit its interpretation of the McCoy claims in suit to substantially the circuitry disclosed in the McCoy patent, and that as so limited the claims are not infringed by the accused Beckman 2100 computer. It is also submitted that the McCoy claims in suit, if interpreted broadly enough to cover the Beckman 2100 are clearly invalid over the art, but if interpreted narrowly enough to avoid such invalidity are not infringed by the 2100.

The defendant Beckman respectfully solicits a reversal of the judgment of the District Court upon the grounds that the McCoy claims in suit are either invalid over the prior art or are not infringed by defendant, or both, and an award of its taxable costs on this appeal and in the District Court.

Dated: August 8, 1969.

Respectfully submitted,

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Jan. 10, 1961 R. D. McCOY 2,967,997
METHOD AND APPARATUS FOR CHECKING
ELECTRONIC ANALOG COMPUTERS
Filed April 20, 1955

Fig. 1.

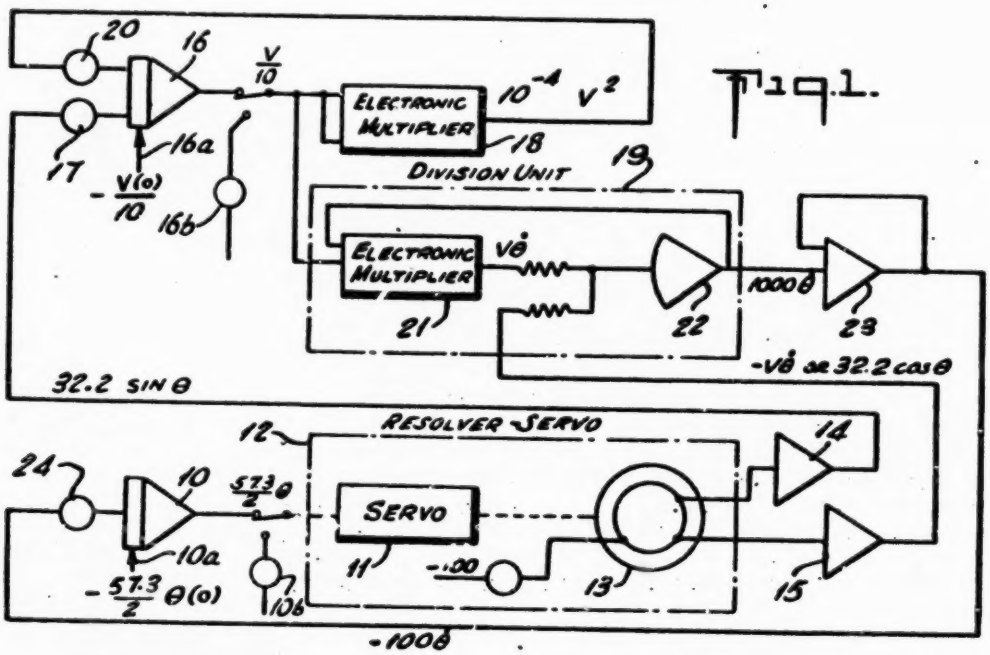
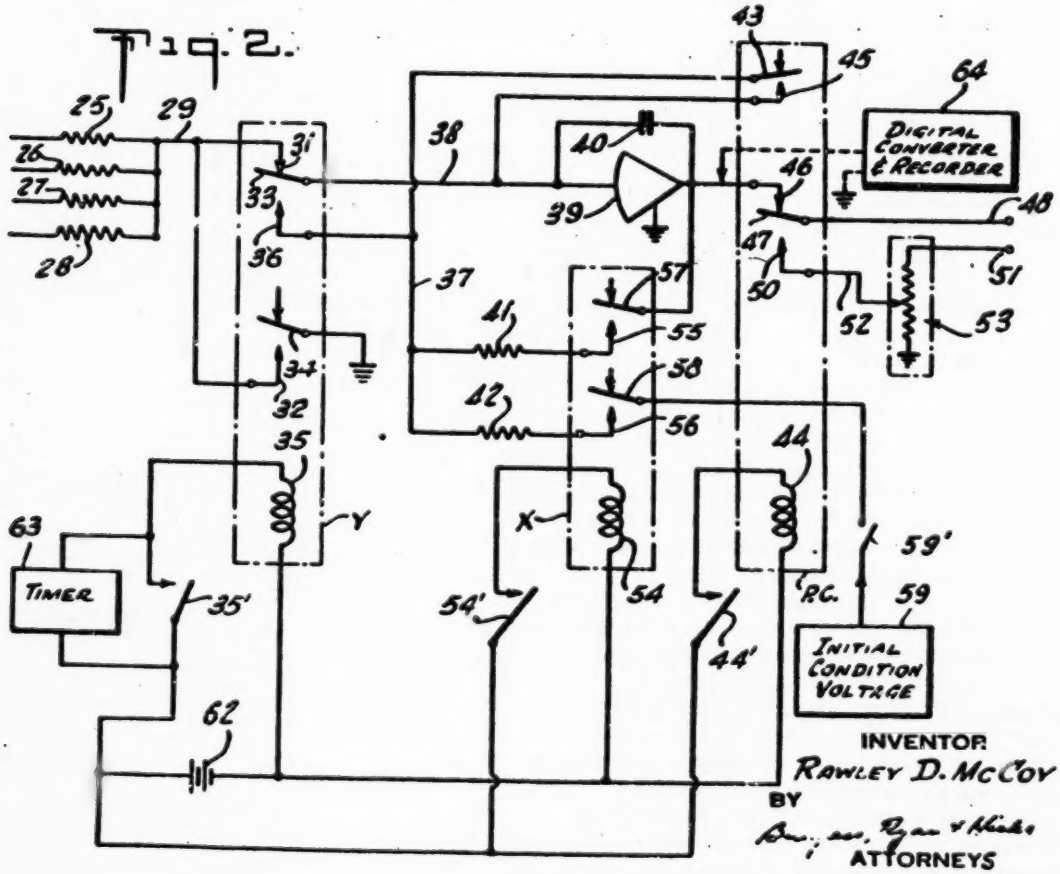


Fig. 2.



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United States Patent Office

Patented Jan. 10, 1961

2,967,997

METHOD AND APPARATUS FOR CHECKING ELECTRONIC ANALOG COMPUTERS

Rawley D. McCoy, Bronxville, N.Y., assignor to Reeves Instrument Corporation, New York, N.Y., a corporation of New York

Filed Apr. 20, 1955, Ser. No. 502,645

14 Claims. (Cl. 324—73)

The present invention relates to electronic computers and relates, more particularly, to a method and apparatus for checking electronic analog computers.

An object of the invention is to provide a method and apparatus by means of which the connections, settings and functioning of the various components of an electronic computer may be readily checked and verified. In accordance with the present invention, such a check may be repeated as often as desired without disturbing the connections or setup of the computer.

Another object of the invention is to provide a method and apparatus for checking an electronic computer by means of which any difficulties or mal-functioning will be localized and can be quickly corrected.

A further object of the present invention is to provide a method and apparatus for checking an electronic computer which may be incorporated in new computer equipment or in existing computer equipment at low cost. Another object of the invention is to provide a method and apparatus for checking an electronic computer which requires a minimum of computation by the operator.

Electronic computers are recognized today as being indispensible tools in the field of Dynamic Systems Engineering. Generally speaking, present day electronic computers have excellent accuracy, but this accuracy is meaningful only if the computer setup which includes problem coding, patch connections and scale factor potentiometer settings are free from error and the components of the computer are operating properly. In setting up a computer for the solution of a particular problem, several hundred or more connections and settings may have to be made by the operator and there is always the possibility of human error in addition to the possibility of improper operation of the components in the computer. Hence, it is of the utmost importance to be able to check the operation of the computer after it has been set up for the solution of a particular problem in order to establish the validity of the results obtained.

Other objects and advantages of the present invention will be apparent and best understood from the following description and the accompanying drawing, in which:

Fig. 1 is a block diagram illustrating an electronic analog computer system embodying the present invention; and

Fig. 2 is a schematic circuit diagram of an integrator embodying the present invention for use in an electronic analog computer system such as shown in Fig. 1.

Referring to the drawings in detail, Fig. 1 illustrates an electronic analog computer which has been set up for the solution of the following equations:

$$\frac{dV}{dt}=-32.2\sin\theta-8(10^{-5})V^2 \qquad (1)$$

$$V\frac{d\theta}{dt}=-32.2\cos\theta \qquad (2)$$

In accordance with accepted nomenclature,

$$\frac{dV}{dt}$$

and

$$\frac{d\theta}{dt}$$

may also be referred to as $\dot{V}$ and $\dot{\theta}$, respectively. V is velocity in feet per second and θ is angle in degrees or radians.

In the computer circuit shown in Fig. 1, there is an integrator 10 which has its output connected to a servo 11 of a resolver-servo unit 12. The resolver 13 of the resolver-servo unit 12 has two outputs which are connected to inverter amplifiers 14 and 15, respectively. The output of the amplifier 14 is connected to an input of a second integrator 16 through a scale factor potentiometer 17.

The output of the integrator 16 is fed to an electronic multiplier 18 and to an electronic division circuit 19. The output of the electronic multiplier 18 is returned to an input to the integrator 16 through a scale factor potentiometer 20.

The electronic division circuit includes an electronic multiplier 21 and a high gain summing amplifier 22. The output of the integrator 16 is connected to the multiplier 21 in the division circuit and the output of the multiplier is connected to the input to the high gain amplifier 22. The output of the inverter amplifier 15 is also connected to the input to the high gain amplifier 22 in the division circuit and the output of the high gain amplifier is returned to the multiplier 21. The output of the high gain amplifier which is the output of the division circuit, is also fed through an inverting an attenuating amplifier 23 to the input of the integrator 10 through a scale factor potentiometer 24.

The symbols used in Fig. 1 are conventional symbols for computer circuits. The electronic multipliers 18 and 21 may be of the type shown in U.S. Patent application Serial No. 294,752, filed June 6, 1952, in the names of Rawley D. McCoy and Leo Wiesner and entitled Electronic Multiplier and Divider, now Patent 2,839,244.

Under certain conditions in the checking mode of operation, as will be described hereinafter, the outputs of the integrators 10 and 16 are disconnected from the circuit and check voltages of predetermined values are substituted in the computer circuit in place thereof from potentiometers 10*b* and 16*b*, respectively.

To condition the computer for operation, constant initial condition input voltages representing $\dot{\theta}$ and V at time zero are introduced into the integrators 10 and 16, respectively, as indicated at 10*a* and 16*a*. During normal operation of the computer, the inputs 10*a* and 16*a* are disconnected from the integrators.

The initial condition voltages $\dot{\theta}$ and V will depend on the characteristics of the computer and in this instance the initia' condition voltage for integrator 10 will be

$$-\frac{57.3}{2}\dot{\theta}_{(0)}$$

and the initial condition voltage for integrator 16 will be

$$-\frac{V_{(0)}}{10}$$

The integrators 10 and 16 are so designed that their outputs will be the same as the initial condition voltages applied thereto except for sign.

In the computer circuit illustrated in Fig. 1, the output of the integrator 10 will be

$$\frac{57.8}{2}\theta$$

The output of the amplifiers 14 and 15 will be 32.2 sin θ and 32.2 cos θ, respectively, and the output of the integrator 16 will be

$$\frac{V}{10}$$

The output of the multiplier 18 will be $10^{-4}V^2$ and the output of the division circuit will be 1000 θ. The output of the amplifier 23 will be $-100\ \theta$.

The outputs of the various components may be calculated and compared with the actual values obtained from the computer under such initial conditions, but this does not provide a complete check because the integrator connections, inputs and performance are not verified.

Fig. 2 illustrates an integrator circuit which includes means for obtaining both a dynamic and a static check on the operation of the computer including integrators such as the integrators 10 and 16 shown in Fig. 1.

In the circuit shown in Fig. 2, there is a series of precision input resistors 25 to 28, inclusive, through which input voltages may be fed to the integrator in the usual manner. One end of each resistor is connected to a common lead or summing junction 29. The summing junction is connected to fixed contacts 31 and 32 of a relay designated by the letter Y. The relay Y has two movable contacts 33 and 34 and an energizing coil 35. When the relay coil 35 is de-energized, the movable contact 33 engages with the contact 31 and the contact 32 is open. When the relay coil 35 is energized, the movable contact 33 is shifted into engagement with a fixed contact 36 and the movable contact 34 engages with the fixed contact 32.

In normal operation of the integrator, the relay coil 35 is de-energized and the input to the integrator is connected through contacts 31 and 33 and a lead 38 to the input of an amplifier 39 which has a feedback condenser 40 connected across it in the usual manner to function as an integrator.

The other movable contact 34 of the relay Y is connected to ground. When the relay is energized, the input voltage is connected to ground through the contacts 32 and 34. At the same time, the input to the integrating amplifier is connected through the contacts 33 and 36 to a lead 37. The lead 37 is connected to one side of each of a pair of resistors 41 and 42 and also to a movable contact 43 of a second relay designated by the letters P.C. having an energizing coil 44.

When the coil 44 is de-energized, the movable contact 43 is open. When the coil 44 is energized, the movable contact 43 engages with a fixed contact 45 and thus connects one side of the resistors 41 and 42 to the input to the amplifier 39.

The relay P.C. also includes a fixed contact 46 which is connected to the output of the integrating amplifier 39 and a movable contact which is connected through a lead 48 to the computer. The movable contact 47 engages with the contact 46 when the relay is de-energized and connects the output of the amplifier to the computer circuit. When the relay P.C. is energized, the movable contact 47 is shifted from the contact 46 to a second fixed contact 50 which is connected by a lead 52 to an adjustable voltage divider 53 in the form of a potentiometer which in turn is connected to a source of fixed voltage 51. Thus, upon energization of the relay, the output of the amplifier is disconnected from the computer and a predetermined voltage from the potentiometer is substituted therefor in the computer.

A third relay denoted by the letter X having an energizing coil 54 is also connected in the integrator circuit for use in the checking operations. The relay X has two

fixed contacts 55 and 56 which are connected to the resistors 41 and 42, respectively. The fixed contacts are open when the relay coil 54 is de-energized. When the relay coil 54 is energized, a movable contact 57 which is connected to the output of the integrating amplifier 39 engages with the fixed contact 55 and a movable contact 58 which is connected to an initial condition voltage source 59 engages with the other fixed contact 56 of the relay.

When either the first relay Y or the second relay P.C. are energized and the third relay X is energized at the same time, the resistor 41 is connected as a feedback resistor across the input and output of the amplifier 39 and cancels the integrating effect of the feedback condenser 40.

An initial condition voltage may also be applied to the input to the integrating amplifier 39 from a source 59 through contacts 56 and 58 of the relay X and the resistor 42 in order to condition the computer for operation. It should be noted, however, that the initial condition voltage source 59 is disconnected by a switch 59' from the relay X during problem check and balance check of the computer as described hereinafter.

The operation of the relays Y, P.C., and X may be controlled by suitable switches 35', 44', and 54' which connect the coils of the respective relays to a source of energy such as a battery 62. In addition, a suitable timing device 63 is provided to control the operation of the relay Y during part of the checking operation and is arranged to energize the coil 35 of the relay Y after a predetermined period of computer operation. It will be understood that one such timing device may be used to control the relays of the several integrators in a computer.

In order to facilitate the checking operation, a read-out device 64 such as a digital converter and recording system is used to measure the output of the integrator. Such a device may be arranged to selectively measure the outputs of the various components in the computer in a desired sequence and to print and record such outputs automatically so that the outputs obtained may be compared with calculated values.

The conditions for operation of the relays to perform both a static and dynamic check of a computer are set forth in the following table.

Relay	Prob. Ck. Static	Prob. Ck. Dynamic	
		Oper.	Hold
X	E	D	D
Y	D	D	E
P.C.	E	E	E

E denotes relay energized.
D denotes relay de-energized.

After the computer has been connected with the proper settings for the computation of a particular problem, a static problem check is first carried out. Under such conditions, the relay P.C. is energized and a constant problem check voltage from the potentiometer 53 is substituted in the computer for the output of the integrator. The relay X is also energized and thus, the amplifier does not function as an integrator. This is done for each integrator in the computer and with the introduction of these constant voltages, output voltages will appear at each component in the computer, the values of which may be read and recorded by the read-out device. Under these conditions, the outputs of the integrators will be proportional to the initial value of the derivatives applied thereto.

Assume problem check initial conditions of V equal to 1000 ft./sec. and θ equal to ¼ radian and with the capacity of the condenser 40 being 1 mfd. and the value of the resistor 41 being 1 megohm, the correct outputs for the computing elements will be:

	Output Factor	Output (Volts)
Integrator 10	$\frac{57.3}{3}\dot{\phi}$	−0.57
Integrator 16	$\frac{\dot{V}}{10}$	−9.06
Amplifier 14	22.2 sine ϕ	10.5
Amplifier 15	22.5 cos ϕ	20.4
Amplifier 22	1000 ϕ	−30.4
Amplifier 23	−100 ϕ	3.04
Multiplier 18	$10^{-4}V^2$	100.0
Multiplier 21	$V\phi$	−30.4

It will be noted that the outputs of integrators 10 and 16 are proportional to the initial value of the derivative of the normal integrator output. The values of the derivatives $\dot{V}$ and $\dot{\phi}$ are determined from the Equations 1 and 2, respectively.

In order to verify the operation of certain nonlinear elements, such as limiters or function generators, and to establish reasonable levels for all of the variables in a system of equations, it may be desirable to insert several values of problem check voltages into the system and this may be done by adjusting the problem check potentiometers without disturbing other connections.

The dynamic problem check is then carried out and in making a dynamic problem check the relay Y is shifted from an operate to a hold position, as indicated in the table. In the operate position, the relay Y is de-energized and the input voltages from the computer are fed to the amplifier 39 and an output voltage is produced. However, the relay P.C. is energized and the problem check initial condition voltage is substituted in the computer circuit in place of the integrator output. During this portion of the operation, each integrator performs its integrating function for a fixed interval of time as determined by the timer 63 and after the predetermined interval of time has elapsed the relay Y is energized by the timer operation and is shifted to the hold position. This interrupts the computing process and the outputs of the integrators are recorded by the read-out device.

Since the time of the integrating operation is known and since the output of each integrator is equal to a constant times the initial values of the derivative of the problem variable computed in each integrator, the outputs of the integrators can be directly checked against values calculated from the original equations. For the sample problem with a nine second integration time, these values will be:

	Output Factor	Voltage
Integrator 10	$-10\left(\frac{57.3}{3}\dot{\phi}\right)$	−8.7
Integrator 16	$-10\,\dot{V}/10$	−90.6

(The proportionality factor is ten instead of nine because of the initial charge on the integrating condensers.)

In this mode of operation, the functioning of the integrating condensers 40 in each of the integrating amplifiers 39 used in the computer may be checked and a complete check of every element in the computing system is accomplished including the patch-board connections and adjustments of the scale factor potentiometers. If the outputs from the integrators, as well as the output voltage of other components of the circuit as determined during the static problem check, meet the requirements of the equations being solved, the connections and settings of the computer are verified as being correct.

After the apparatus has been checked both statically and dynamically, normal operating procedures may be followed as indicated in the following table.

Relay	Bal. Ck.	Reset	Operate	Hold
X	E	E	D	D
Y	E	E	D	E
P.C.	D	D	D	D

The balance check conditions as indicated in the above table is for the purpose of determining that all amplifiers are working properly and are drift-free. This is in effect a maintenance mode of operation. The reset mode of operation provides for the insertion of initial condition voltages into each of the integrators. During the operate mode all of the relays are de-energized for operation of the computer.

As described above, the utilization of three separate relays within the circuit of each integrator in the computer permits the entire computing system to be accurately checked to assure the proper arrangement of the computer components to attain a desired end. While individual switches have been shown as operating the three relays in Fig. 2 of the drawings, it will be understood that corresponding relays in the various integrators in a computer may be simultaneously operated by means of suitable master switches and a single timer may be employed to operate the Y relays in all of the integrators in the computer.

By incorporating the three control relays and the associated circuits in the integrators for a computer, the necessity for manually modifying any computer connections whatsoever in the performance of both the static and the dynamic problem checks is avoided and enables the operator to check the operation of the computer whenever desired by merely operating the appropriate switches. Also, where the computer is provided with so-called "prepatch" boards which enable the connections for the solution of the particular problem to be set up independently of the computer, the connections and operation of the computer can be checked both statically and dynamically and after the check results are obtained the operator can then re-study the particular setup away from the computer which in the meantime may be utilized for other purposes. This procedure greatly increases the usefulness of computers since it is not necessary to occupy the apparatus for extended periods of time to determine the accuracy of a particular setup and locate possible errors therein.

It will be understood that various alterations, modifications and changes may be made in the embodiment of the invention illustrated and described herein without departing from the true scope and spirit thereof.

I claim:

1. In an apparatus for checking the operation of an analog computer which includes an integrator having an input and an output connected in the computer circuit, the combination which comprises means for disconnecting the output of the integrator from the computer circuit and substituting a predetermined voltage in the computer circuit in place thereof, means for disconnecting the input to the integrator from the computer circuit after a predetermined period of operation of the integrator with its output disconnected from the computer circuit, and means for measuring the output of the integrator after said predetermined period of operation.

2. In an apparatus for checking the operation of an electronic analog computer which includes an integrator having an amplifier and a feedback condenser connected across the amplifier, said integrator having an input and an output connected in the computer circuit, the combination which comprises means for disconnecting the output of the integrator from the computer circuit and substituting a constant voltage of a predetermined value in the computer circuit in place thereof, means including a resistor for cancelling the effect of the feedback condenser in the integrator, and means for measuring the

output of the integrator when the effect of the condenser is cancelled.

3. In an apparatus for checking the operation of an electronic analog computer which includes an integrator having input and output circuits connected in the computer circuit, the combination which comprises adjustable means connected to a source of constant voltage for providing a voltage, having a predetermined value, means for disconnecting the output of the integrator from the computer circuit and connecting the predetermined voltage from said adjustable means to the computer in place of the integrator output, means for disconnecting the input of the integrator from the computer circuit after a predetermined period of operation of the integrator, and means for measuring the integrator output after said predetermined period of operation.

4. Apparatus for checking the operation of an analog computer having an integrator including an amplifier and a feedback condenser connected across the amplifier, said integrator having an input and an output connected to the computer circuit, comprising means for rendering the condenser ineffective, means for disconnecting the output of the integrator from the computer and substituting a constant voltage of predetermined value in the computer circuit in place thereof, said last-mentioned means including a potentiometer connected to a source of constant voltage, and indicating apparatus adapted to be connected to the output of said integrator for measuring the output therefrom while said integrator is ineffective.

5. Apparatus for checking the operation of an electronic analog computer including an integrator, said integrator including an amplifier having an input and an output connected in the computer circuit and an integrating condenser interconnecting the input and output of the amplifier, which comprises a resistor, a relay operable to shift the input of the amplifier from the computer circuit to one side of the resistor, means adapted for supplying a predetermined voltage to the computer circuit, a second relay operable to shift the computer circuit connection from the output of the amplifier to the means for supplying a predetermined voltage and also to connect the said one side of the resistor to the input of the amplifier, a third relay operable to connect the other side of the resistor to the output of the amplifier, and voltage measuring means coupled to the output of said integrator.

6. Apparatus for checking the operation of an integrator as defined in claim 5 further comprising timing means for controlling the operation of the first mentioned relay for a predetermined time interval.

7. In an analog computer including an integrating circuit, said integrating circuit having input and output terminals coupled to the remaining elements of said analog computer for forming a closed-loop feedback system, the combination for testing the analog computer system comprising switching means coupled to said integrating circuit, said switching means opening the loop of the feedback system and rendering said integrating circuit ineffective, means supplying a fixed voltage to the opened-loop system, said fixed voltage being translated through said opened-loop system to the input of said integrating circuit, and means coupled to the opened-loop system for measuring the voltage appearing at the input of said integrating circuit.

8. In an analog computer including an integrating circuit having an amplifier with input and output terminals and a common terminal, said integrating circuit including condenser means coupled between the input and output terminals of said amplifier and further including an input resistor coupled in series with the input of said amplifier, said integrating circuit being coupled to the remaining elements of said analog computer for forming a closed-loop feedback system, the combination for testing the analog

computer system comprising shunt resistor means, switching means coupled to said integrating circuit and said shunt resistor means, said switching means opening the loop of the feedback system and coupling said shunt resistor means across said condenser means, means supplying a fixed voltage to the opened-loop system, said fixed voltage being translated through said opened-loop system to the input of said integrating circuit, and means coupled to the opened-loop system for measuring the voltage appearing between the input terminal of said input resistor and said common terminal.

9. The apparatus as defined in claim 8 wherein said switching means disconnects the output of said amplifier from the remaining elements of said analog computer.

10. The apparatus as defined in claim 9 wherein said switching means coupling said shunt resistor means across said integrating condenser converts said integrating circuit into a negative feedback amplifier circuit having a predetermined gain, and wherein said means coupled to the opened-loop system for measuring the voltage appearing between the input terminal of said input resistor and said common terminal includes voltage measuring means coupled to the output terminals of said negative feedback amplifier circuit.

11. In an analog computer system having a plurality of integrating circuits, said integrating circuits each having an input and an output, the combination for testing each of said plurality of integrating circuits comprising switching means coupled to each of said plurality of integrating circuits, said switching means being adapted for coupling a known voltage to the input of each integrating circuit, means coupled to said switching means for automatically controlling the time interval that the known voltage is coupled to the input of each of said integrating circuits, and measuring means adapted to be coupled to the output of each integrating circuit for measuring the output voltage therefrom following said time interval.

12. In an analog computer system including at least one integrating circuit, said integrating circuit having an input adapted to be coupled to first terminal means of the remaining elements of said computer and having an output adapted to be coupled to second terminal means of the remaining elements of said computer for forming a closed-loop system, the combination for testing the remaining elements of said computer comprising means including switching means and a source of known voltage coupled to said analog computer system for supplying a known voltage to said second terminal means, said known voltage being translated through the remaining elements of said analog computer to said first terminal means, and measuring means including amplifier means coupled to said first terminal means for measuring the response of the remaining elements of said analog computer to said known voltage.

13. Apparatus for testing an analog computer including at least one integrating circuit, said integrating circuit having an input coupled to first terminal means of the remaining elements of the computer and an output coupled to second terminal means of the remaining elements of the computer to form a closed-loop system, the input of said integrating circuit including a series input resistor, comprising in combination, means including switching means coupled to said integrating circuit, a source of known voltage coupled to said switching means, said switching means rendering said integrating circuit ineffective and supplying a known voltage to said second terminal means of the computer, said known voltage being translated through the remaining elements of the computer to the series input resistor of said integrating circuit, and measuring means including amplifier means

coupled to said series input resistor for measuring the response of the remaining elements of the computer to said known voltage.

14. The apparatus for testing an analog computer as defined by claim 13 wherein said amplifier means associated with said measuring means forms a part of said integrating circuit.

References Cited in the file of this patent

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